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Insecticide Investigations

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CORVALLIS, OREGON

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Insecticide Investigations

SUMMARY

1. The acid arsenate of lead has a higher killing efficiency than has the basic salt.

2. All the arsenic devoured by caterpillars feeding upon sprayed foliage is not assimilated, a portion passing through the digestive tract in the excrement. The proportion assimilated is higher where an acid arsenate is employed. This accounts for the higher killing efficiency of the acid lead arsenate.

3. Under laboratory control conditions a dilution of 1 pound of the acid lead arsenate to 400 gallons of water proved an effective killing solution for very small tent caterpillars. It is reasonable to assume that newly hatched codling-moth larvae are no less susceptible to poison.

4. The commercial lead arsenates on the market, unless specifically prepared and labeled otherwise, are nearly pure acid lead arsenate.

5. The powdered lead arsenates are physically superior to the paste forms and are generally the advisable form to use. Particularly is this true if one is not near the point of manufacture, so as to insure a freshly made paste, which has had no opportunity to dry out or freeze.

6. Allowing for the natural factors which render ideal control conditions impossible in commercial orchard spraying, the apparent discrepancy between the theoretical killing dosage of arsenate and the standard dosage in vogue is due in part to physical defects: (a) In the methods of application of spray. (b) In the spray solution. (c) In the spray material.

7. Commercial lead arsenates are in general a standard product. They vary but slightly in the percentage of arsenic carried or in the low percentage of soluble arsenic present. In their physical properties there is considerable variation.

8. By improving the physical properties of the spray solution we are enabled to improve the efficiency of the spray: (a) By increasing the wetting and covering power of the spray solution. (b) By increasing its adhesiveness.

9. Materials added for this purpose are termed spreaders.

10. The spray solution, without the addition of a spreader, as normally applied to the waxy surface of an apple finally rests as an irregular, blotchy coating of uneven thickness and with interspaces but poorly coated or free from spray.

11. The spray solution, with a spreader, applied to the surface of the apple finally rests as a smooth, even, inconspicuous covering, affording practically an equal and perfect protection for every surface.

12. Materials showing value as spreaders in the poison spray solution, given in order of their merit, based on compatability, efficiency, availability, cost and ease of preparation are: caseinate, glue, gelatine,* soap bark, and oil emulsion.

13. In preliminary experiments conducted thus far these spreaders are not improved by the addition of phosphates and sulfates.

14. Methods have been developed for testing the comparative wetting values of spreaders for the surface of the apple fruit by means of capillary tubes.

15. The improvement of the physical condition of any one of the three factors, method of application, the spray solution, and the spray material, decreases the relative importance of defects in the other two.

a. The physical properties of the spray material and of the spray solution are inversely proportional to the power and agitator effectiveness of the outfit. Where the agitator is faulty or mediocre, where the pressure capacity is limited, or the spray nozzle defective, the efficiency value of improved solution and materials rapidly increases in importance.

b. The importance of the capacity of the outfit and physical qualities of the material are inversely proportional to the wetting, covering, and adhesive properties of the spray solution.

c. The importance of the physical solution and capacity of outfit is inversely proportional to the fineness, uniformity of division, powers of suspension, and adhesiveness of the spray material.

16. Where the physical qualities of all three are developed to the highest possible standard we should, in the hands of a careful manipulator, approach the ideal protective covering sought for in a spray application.

17. A fine, misty spray applied in the calyx application for codling-moth control is equal in effectiveness to a driving spray.

18. The total calyx worms in the commercial orchard in Oregon is usually less than 50 percent of the total worm infestation.

19. In commercial orchards in Oregon, where a spray program is practiced, the worm infestation is normally light until late summer. Data accumulated for a series of years show that it is the late summer brood of moths giving rise to the worms which infest the fruit during late August and early September causing the costly "September sting" that is responsible for our heavy losses from wormy fruit.

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* For discussion of gelatine see under Conclusion page 50.

20. To attach undue importance to the calyx application has not been found warranted in our experiments. All applications are essentially of equal merit, and conscientious effort in their application is desirable. The last summer application is particularly significant because of the difficulty in timing it properly.

21. The calcium arsenates have a high killing efficiency as a poison spray for chewing insects.

22. They are not as stable as are the corresponding lead salts and for use in commercial orchard spraying, under Western Oregon conditions, it is advisable to have an excess of lime present in the solution.

23. Methods of manufacture have not been standardized, and commercial brands of calcium arsenate vary greatly in their chemical and physical properties.

24. There is at present probably no adequate reason for a wholesale abandonment of the lead in favor of the calcium arsenate for orchard work.

25. Nicotine sulfate is a powerful repellent for tent caterpillars. They will not ordinarily feed from choice on foliage sprayed with it.

26. Where feeding does take place, the action of the nicotine is apparently rapid and sure. Foliage in small bits sprayed with comparatively weak solutions, where devoured, kills almost instantly.

27. Nicotine sulfate is an effective ovicide for codling-moth eggs. The addition of soap renders it practically perfect in this regard.

28. As a substitute for the standard arsenical sprays for codling-moth control, efficiency and cost considered, nicotine sulfate does not show qualities to recommend its general adoption.

29. The use of nicotine sulfate as a supplement to and in certain combinations with the standard arsenate sprays may, under certain conditions, prove highly practical: (a) As a substitute for the arsenate spray in the July application where a serious summer reinfestation of aphids is present. (b) In combination with the last summer application of arsenate (plus a spreader) as a further insurance against the "September sting."

INTRODUCTION

The present bulletin is a report on the progress of an investigation on poison insecticides under way at the Oregon Agricultural College Experiment Station.

This project was launched in 1914 by Professor H. F. Wilson and carried forward by him until September, 1915, when he resigned from the station and the author continued the investigation.

A similar investigation of insecticides has been under way in the department of Chemistry. In many phases of the work these two projects have merged and become interdependent, and cooperative laboratory and field tests have been made. All chemical work reported in this bulletin is properly credited to the department of Agricultural Chemistry, to which much credit is due for such progress as has been possible.

The first part of the bulletin consists of a review and summary of the earlier investigations under this project. The report subsequent to 1916 is divided into three subheads or investigations. First, an investigation of the physical properties of the spray solution and of the spray material. Second, an investigation of calcium arsenates. Third, an investigation of nicotine sulfate as a poison spray.

EARLIER WORK

The earlier investigation by Wilson[1] had to do with a test of possible materials that might prove effective as poison insecticides. Summarizing this work it may be said that the arsenates of lead, acid and basic, all things considered, were found the most acceptable poison materials for general orchard spray practices.

Robinson and Tartar[2] during this period developed standard methods for the production of pure arsenates of lead and in subsequent tests of these materials, unless otherwise indicated, the material used was the pure salts as prepared by the chemists.

PROPERTIES OF THE ARSENATES

Because of the frequent use of these pure forms of arsenate of lead in our spray tests and due to their close relationship to commercial brands of lead arsenate on the market a short discussion of some of their properties is given.

Physical Properties. The acid salt, lead hydrogen arsenate, is of a fluffy, flour-like consistency, light and bulky. The neutral salt, basic lead arsenate, is of a granular consistency, heavy and compact. The comparative specific gravity is:

Acid lead arsenate	Sp. gr. 5.786
Basic lead arsenate	Sp. gr. 7.105

Chemical Properties. The acid salt contains a higher percentage of arsenic than does the basic:

Lead hydrogen arsenate, total As_2O_5	32.9
Basic lead arsenate, total As_2O_5	23.4

[1]Wilson, H. F. 1915. Insecticide Investigations of 1914. 2nd Bien. Crop Pest and Hort. Rept. Ore. Agri. Col. Exp. Sta. 1915. p. 137.

[2]Robinson, R. H., and Tartar, H. V. 1915. The Arsenates of Lead. Ore. Agri. Col. Exp. Sta. Bul. 128.

The acid lead arsenate stays in suspension in solution well, has a high percentage of arsenic present, and, as we shall see later, kills more quickly than does the basic form. It is less stable than the basic and in questionable combinations or on very tender foliage would have more of a tendency to burn.

The basic lead arsenate does not stay in suspension well, carries a lower percentage of arsenic, and kills more slowly. It is the more stable compound; therefore, in combination sprays and on tender foliage, where there is danger of burn, it is the safer form to use.

The commercial lead arsenates on the market are in general largely the acid lead arsenate form unless specifically prepared and labeled otherwise.

TOXIC VALUES AND KILLING EFFICIENCY OF THE ARSENATES

The main investigation carried forward under this project in 1915 and 1916 had to do with testing the relative efficiency and toxic values of pure samples of lead hydrogen arsenate (acid) and basic lead arsenate (neutral). The two-year investigation discussed here constitutes a joint problem between the departments of Chemistry and Entomology. The investigation during 1915 was in charge of Professor Wilson and Professor Tartar and the season's results were published by them.[3]

Professor Wilson left the department of Entomology in 1915. About this time most of the chemical investigational work on insecticides was placed in charge of Mr. R. H. Robinson. The investigations of 1916 were, therefore, in charge of Mr. Robinson and the author. The results of this season's work, which were likewise published,[4] served to verify and amplify the results of the previous season.

It is believed that a brief resume of this investigation and a summary of the results will be of value (1) in establishing the relative position of the two forms of arsenate; (2) in indicating the low dilution of arsenate required to kill; (3) as a basis for the discussion of subsequent investigations prompted by these results and founded on them.

TESTS OF 1915

Properly to test the relative values of various dilutions of poison it is desirable to have some leaf-eating insect reasonably plentiful and capable of devouring considerable quantities of sprayed foliage.

Experimental Procedure. Our common tent caterpillar (*Malacosoma pluvialis*) was finally used as the medium for the tests, and was used throughout the series of experiments. This caterpillar occurs in numbers during April, May, and June, feeding largely on the wild rose (*Rosa mukatana*) though occurring on a variety of hosts including apple. The caterpillars feed gregariously in tents of a hundred or more in a colony. They eat greedily and were found to feed readily on sprayed foliage.

Apple foliage was used in these tests. The leaves were kept attractive by placing the treated twigs in containers of water. The poisons were used in varying dilutions to determine a killing strength and their

[3]Tartar and Wilson. 1915. Toxic Values of the Arsenates. Jour. Econ. Ent. VIII, p. 481.

[4]Lovett and Robinson. 1916. Toxic Values and Killing Efficiency of the Arsenates. Jour. Agr. Research, X. p. 199.

comparative efficiency. Trials in preparing the poison foliage to get a smooth, even covering included dipping and spraying. No marked difference in effectiveness of the two methods was apparent. In the actual tests, therefore, the solution was applied as a spray using an ordinary quart-size, hand sprayer, care being observed to keep the material agitated and to get the solution thoroughly applied and evenly distributed. The solution was allowed to dry on the foliage before introducing the caterpillars.

Nearly mature larvae were used in these tests. Following the introduction of the caterpillars to the sprayed foliage, daily observations were made. The dead caterpillars were collected, counted, placed in vials, and labeled. At the conclusion of the test these dead caterpillars were analyzed for the arsenic content.

The following strengths were used:

SERIES I

2 to 50 gallons of water (L.H.A. and B.L.A.*) 10.3 grams to 2000 cc. H_2O
2 to 100 gallons of water (L.H.A. and B.L.A.) 5.18 grams to 2000 cc. H_2O
2 to 200 gallons of water (L.H.A. and B.L.A.) 2.59 grams to 2000 cc. H_2O
2 to 400 gallons of water (L.H.A. and B.L.A.) 1.295 grams to 2000 cc. H_2O
2 to 800 gallons of water (L.H.A. and B.L.A.) .6475 grams to 2000 cc. H_2O
The first three sets were applied April 22, the other two April 23, 1915.

SERIES II

2 to 50 gallons of water (L.H.A. and B.L.A.) 2.59 grams to 500 cc. H_2O
2 to 100 gallons of water (L.H.A. and B.L.A.) 1.281 grams to 500 cc. H_2O
2 to 200 gallons of water (L.H.A. and B.L.A.) .647 grams to 500 cc. H_2O
2 to 400 gallons of water (L.H.A. and B.L.A.) .3237 grams to 500 cc. H_2O
2 to 800 gallons of water (L.H.A. and B.L.A.) .1618 grams to 500 cc. H_2O
2 to 1200 gallons of water (L.H.A. and B.L.A.) .1067 grams to 500 cc. H_2O
The first series was applied May 5; the other five May 4.

A summary of the tests including the daily kill and effectiveness of the various strengths of the arsenates is included in Table I.

TABLE I. EFFECTS OF ARSENATES ON CATERPILLARS, 1915

Series I

No.	Strength and kind of spray	Date applied	Drop April 24	April 25	April 26	April 27	April 28	April 29	Total drop
1	2-50 L.H.A.	Apr. 22, 1915	325	46	30	20	24	.....	445
	2-50 B.L.A.	Apr. 22, 1915	12	17	98	48	30	.....	205
2	2-100 L.H.A.	Apr. 22, 1915	56	101	94	51	39	.....	341
	2-100 B.L.A.	Apr. 22, 1915	.....	7	23	82	57	33	272
3	2-200 L.H.A.	Apr. 22, 1915	46	60	103	121	33	9	372
	2-200 B.L.A.	Apr. 22, 1915	.....	5	6	40	101	68	220
4	2-400 L.H.A.	Apr. 23, 1915	.....	.....	88	57	104	83	332
	2-400 B.L.A.	Apr. 23, 1915	.....	.....	14	42	57	88	201
5	2-800 L.H.A.	Apr. 23, 1915	.....	.....	43	110	177	88	418
	2-800 B.L.A.	Apr. 23, 1915	.....	.....	3	43	108	137	291

* L.H.A.=Lead Hydrogen Arsenate; B. L. A.=Basic Lead Arsenate.

Series II

No.	Sprays		Date applied	May 5	May 6	May 7	May 8	May 9	May 10	May 11	May 12	May 13	Summary total drop
1	2-50	L.H.A.	May 5	.....	21	103	83	69	36	33	5	2	352
	2-50	B.L.A.	May 5	.....	3	128	169	53	201	126	66	38	784
2	2-100	L.H.A.	May 4	9	45	69	95	3	19	.....	.....	(all dead)	240
	2-100	B.L.A.	May 4	.....	6	17	108	19	41	.....	.....	.....	191
3	2-200	L.H.A.	May 4	65	123	209	118	31	107	.....	.....	.....	653
	2-200	B.L.A.	May 4	.....	12	77	139	34	75	46	20	.....	403
4	2-400	L.H.A.	May 4	19	77	154	192	44	85	33	.....	.....	604
	2-400	B.L.A.	.....	.....	5	21	87	65	42	34	30 (20 more or less alive)	.....	284
5	2-800	L.H.A.	.....	5	61	106	175	59	97	30	35 (several alive)	.....	568 .....
	2-800	B.L.A.	.....	.....	3	12	49	21	36	25	6	.....	152
6	*2-1200	L.H.A.	.....	.....	12	36	163	115	77	42	93 (picked off)	23 (a few alive)	561
	2-1200	B.L.A.	.....	.....	.....	7	23	44	39	46	42 (picked off)	22	223 (at least 25 feeding on first foliage)

* Where strengths of 2 to 1200 were used it was necessary to add a second set of sprayed twigs, as caterpillars ate all foliage on first set.

Discussion of Results. Lead hydrogen arsenate is a quicker acting poison than is the basic lead arsenate. In dilutions of 2 pounds of arsenate to 200 gallons of solution, both forms show a satisfactory killing efficiency. At dilutions of 2-400 the acid lead arsenate is still effective, but the basic form no longer shows satisfactory results. At dilutions of 2-1200 neither material was sufficiently active to prove satisfactory as a toxic dosage.

TABLE II. ANALYSIS OF DRIED CATERPILLARS FOR ARSENIC

Series I

No.	Spray	No. of caterpillars	Weight of dry tissue	Weight of arsenic oxide (As_2O_5)	Milligrams of arsenic oxide (As_2O_5) to 1 gram of dry tissue
			g.	mg.	mg.
1	2-50 L.H.A.	445	3.976	2.96	0.74
2	2-50 B.L.A.	205	1.423	0.86	0.60
3	2-100 L.H.A.	341	1.262	0.86	0.68
4	2-100 B.L.A.	202	1.623	0.48	0.30
5	2-200 L.H.A.	371	1.751	0.40	0.23
6	2-200 B.L.A.	220	1.056	Trace*	.....
7	2-400 L.H.A.	332	1.674	0.34	0.20
8	2-400 B.L.A.	201	.831	Trace	.....
9	2-800 L.H.A.	418	1.337	0.08	0.06
10	2-800 B.L.A.	291	2.035	0.28	0.14

* One drop fiftieth normal iodine for titration.

TABLE II (continued)

Series II

No.	Spray	No. of caterpillars	Weight of dry tissue	Weight of arsenic oxide (As_2O_5)	Milligrams of arsenic oxide (As_2O_5) to 1 gram of dry tissue
			g.	mg.	mg.
1	2-50 L.H.A.	176	3.383	2.30	0.68
2	2-50 B.L.A.	261	3.520	1.72	0.49
3	2-100 L.H.A.	240	4.046	1.86	0.46
4	2-100 B.L.A.	191	3.150	1.50	0.47
5	2-200 L.H.A.	185	2.990	0.72	0.24
6	2-200 B.L.A.	453	4.835	1.29	0.26
7	2-400 L.H.A.	302	3.790	0.86	0.23
8	2-400 B.L.A.	284	3.222	0.57	0.18
9	2-800 L.H.A.	284	3.719	0.43	0.11
10	2-800 B.L.A.	152	2.303	0.15	0.06
11	2-1200 L.H.A.	280	3.582	0.28	0.08
12	2-1200 B.L.A.	223	2.354	0.15	0.06

Chemical Analysis. A full discussion of the methods of procedure employed in conducting the chemical analyses in the poison tests of 1915 and 1916 is included in the original papers. For our present purpose it is sufficient to say that known quantities of the dried caterpillars were prepared and chemically analyzed for arsenic. The results of these tests for 1915 are summarized in Table II.

Discussion of Results. The arsenic content of the caterpillars poisoned with the lead hydrogen arsenate was nominally the greater; this may be partly due to the higher arsenic content of the acid form. It is also possible that this acid arsenate, being less stable, is more readily acted upon by the digestive juices of the caterpillar, permitting more rapid absorption by the tissues, while the more inert basic arsenate passes through the digestive tract of the caterpillar with the feces.

TESTS OF 1916

The conclusion drawn from the results of 1915 that the lead hydrogen arsenate is more readily absorbed into the tissues of the caterpillar was the basis for a repetition of these tests in 1916. The work was repeated on a somewhat more elaborate scale. The results of these tests, in addition to affording further verification of the findings of Tartar and Wilson, give material data on the following points: (1) The comparative time required to kill small and nearly mature caterpillars. (2) The approximate amount of lead hydrogen arsenate and of basic lead arsenate required to kill small and nearly mature caterpillars. (3) The proportion of these arsenates devoured by the caterpillars that passes through the intestinal tract of the larvae.

Tests of the comparative killing efficiency of pure calcium arsenate were included.

Experimental Procedure. The same species of tent caterpillar was used as in the tests of 1915. Two series of tests were run, (1) with very small larvae, (2) with nearly mature caterpillars.

All the caterpillars to be used in any one series were collected the same day. Care was exercised to obtain for the tests a uniform mixing of the larvae from a series of colonies. Approximately 1000 caterpillars were used for each test. From time to time a few larvae would drop from the foliage and crawl away. These were always discarded.

In the earlier tests both rose and apple foliage were used. As the caterpillars were collected principally from the wild rose it was considered possible that for a time they might refuse apple foliage and then feed on it to excess when they did begin. Since lead arsenate and water failed to stick well or spread evenly on rose leaves, flour paste (1 pound flour to 1 gallon water) was prepared. This gallon of paste was diluted with water to make 3 gallons and used at the rate of 20 c.c. to the 1000 c.c. of the spray solution on rose foliage.

TABLE III. EFFECT OF ARSENATES ON VERY SMALL CATERPILLARS

Kind and strength of solution	Foliage	Date sprayed	Drop (April)														
			9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
		Apr.															
Lead hydrogen arsenate (acid) (2-50)	Rose	8	48	65	92	449	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	654
Do.	Apple	8	17	19	*752	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	788
Basic lead arsenate (neutral) (2-50)	Rose	8	39	155	181	141	720	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,236
Do.	Apple	8	5	22	163	83	522	.....	.....	.....	.....	.....	.....	.....	.....	.....	795
Calcium arsenate (2-50)	Rose	8	41	101	202	63	659	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,066
Do.	Apple	8	28	116	75	69	752	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,040
Lead hydrogen arsenate (acid) (1-50)	Rose	8	49	84	160	1,264	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,557
Do.	Apple	8	27	54	88	859	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,028
Basic lead arsenate (neutral) (1-50)	Rose	8	15	43	100	71	729	.....	.....	.....	.....	.....	.....	.....	.....	.....	958
Do.	Apple	8	23	131	243	253	51	807	.....	.....	.....	.....	.....	.....	.....	.....	1,508
Lead hydrogen arsenate (acid) (1-400)	Rose	8	.....	7	24	74	259	298	518	.....	.....	.....	.....	.....	.....	.....	1,180
Do.	Apple	8	.....	7	62	236	424	1,151	.....	.....	.....	.....	.....	.....	.....	.....	1,880
Basic lead arsenate (neutral) (1-400)	Rose	8	.....	4	6	23	39	63	36	.....	†104	.....	119	.....	165	*342	891
Do.	Apple	8	.....	4	3	1	15	4	0	.....	†101	.....	320	.....	.....	*1,035	1,483
Lead hydrogen arsenate (acid) (1-800)	Rose	9	.....	.....	9	124	49	33	†59	.....	111	121	†27	.....	140	.....	673
Do.	Apple	9	.....	.....	16	45	0	195	†113	.....	179	37	†13	.....	312	.....	910
Lead hydrogen arsenate (acid) (1-1,200)	Rose	9	.....	.....	21	93	247	313	†157	.....	390	156	†47	.....	.....	*342	1,766
Do.	Apple	9	.....	.....	18	23	47	98	†54	.....	126	44	†24	.....	.....	*310	744
Control	Rose	8	.....	.....	.....	.....	(†)	.....	.....	.....	(†)	.....	.....	(§)	.....	.....	.....

* Very few; 15 to 20 yet on foliage show feeble signs of life.
† New foliage prepared and added.
§ Discontinued.

In applying the spray and introducing the worms the same general method of procedure was followed as in the previous tests. Every day,

Sundays excepted, following the introduction of the caterpillars, the dead larvae (drop) were collected from the oilcloth spread under the vessels containing the foliage. The twig was first jarred sharply to dislodge any dead caterpillars that might be caught in the web. The caterpillars were picked up one at a time, carefully brushed with a camel's-hair brush, and placed in a paper bag, which was labeled with the test number, date, and total drop for the day. The excrement was then collected and run through a fine soil sieve to remove any bits of foreign material. Pieces of leaves, molted skins, etc., were carefully removed. The excrement was then placed in glass vials, properly labeled, and filed for analysis, after which the oilcloth was washed and dried.

The calcium arsenate used in the tests was prepared by Mr. R. H. Robinson of the department of Agricultural Chemistry and approximated a pure calcium hydrogen arsenate, $CaHAsO_4$.

Experiments, Series A, Very Small Caterpillars. The caterpillars employed in series A were the very small ones and varied in size from those just hatched to forms about 5 to 7 days old (approximately 10 mm. in length).

The strength of solutions used, date of application, and daily drop are recorded in Table III.

Experiments, Series B, Nearly Mature Caterpillars. Series B was similar in every way to series A except that the caterpillars used were from half-grown to nearly mature larvae and only apple foliage was used. The results are given in Table IV.

TABLE IV. EFFECT OF ARSENATE ON NEARLY MATURE LARVAE

Kind and strength of solution	Date sprayed	Drop (May)															Total
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
	May																
Lead hydrogen arsenate (acid) (2-50)	4	40	39	.....	264	286	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	629
Basic lead arsenate (neutral) (2-50)	4	.....	.....	.....	121	287	.....	46	.....	.....	.....	.....	.....	.....	.....	.....	454
Calcium arsenate (2-50)	4	188	194	.....	113	221	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	716
Lead hydrogen arsenate (acid) (1-50)	4	38	373	.....	392	217	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,020
Basic lead arsenate (neutral) (1-50)	4	.....	.....	.....	87	234	125	43	.....	.....	.....	.....	.....	.....	.....	.....	489
Calcium arsenate (1-50)	4	136	371	.....	334	241	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,082
Lead hydrogen arsenate (acid) (1-100)	5	.....	82	.....	483	331	.....	98	.....	.....	.....	.....	.....	.....	.....	.....	994
Lead hydrogen arsenate (acid) (1-400)	5	.....	6	.....	22	163	162	*151	426	107	136	.....	.....	.....	.....	.....	1,173
Calcium arsenate (1-400)	4	.....	73	.....	481	397	116	124	.....	.....	.....	.....	.....	.....	.....	.....	1,191
Lead hydrogen arsenate (acid) (1-800)	5	.....	12	.....	34	123	164	*203	279	108	.....	.....	201	.....	.....	.....	1,124
Calcium arsenate (1-800)	4	.....	10	.....	152	370	191	117	.....	.....	.....	.....	.....	.....	.....	.....	840
Lead hydrogen arsenate (acid) (1-1,200)	5	.....	7	.....	2	16	23 (*)	*33	145	187	.....	153 (*)	*103	.....	318 (†)	39	1,026
Control	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

* New foliage prepared and added.
† Two parasitized.

Discussion of Results. The results of the tests to determine the relative killing efficiency of the hydrogen and basic lead arsenate as shown by data contained in the above tables and summarized in Table VI approximate very closely those obtained by Tartar and Wilson in 1915 and substantiate in general the work of previous investigators, in that acid arsenate has a decidedly higher killing efficiency at a given dilution than does the neutral arsenate. It will be noted that the figures in the tables do not emphasize the difference in killing efficiency of these arsenates, particularly with the more concentrated solutions, but observation during the actual tests showed the difference clearly. Had the drop been recorded more frequently than every twenty-four hours, this difference, as indicated in the tables, would probably have been more marked. From Tables IV and VI it is seen that until the fourth day no caterpillars died on the twigs sprayed with neutral lead arsenate, while both the acid lead arsenate and calcium arsenate were very effective toxic agents on the first day. In regard to rapidity of action and killing efficiency, calcium arsenate and acid lead arsenate were approximately the same.

TABLE V. ARSENIC CONSUMED BY CATERPILLARS

Kind and strength of solution	Number of caterpillars	Dry caterpillars			Dry excrement		
		Weight	Arsenic pentoxid: Total	Arsenic pentoxid: Per grm. of tissue	Weight	Arsenic pentoxid: Total	Arsenic pentoxid: Per gr. excrement
		g.	mg.	mg.	g.	mg.	mg.
Very Small Caterpillars							
Lead hydrogen arsenate (acid) (2-50)	1,442	0.3130	0.23	0.74	0.0200	0.058	0.28
Lead hydrogen arsenate (acid) (1-400)	3,060	1.0625	.17	.19	.3700	.086	.23
Lead hydrogen arsenate (acid) (1-800)	1,583	.7200	.12	.18	.3400	.086	.25
Lead hydrogen arsenate (acid) (1-1,200)	2,510	.9870	.14	.15	.4500	.12	.25
Basic lead arsenate (neutral) (2-50)	2,031	.5500	.17	.31	.0900	.065	.72
Basic lead arsenate (neutral) (1-50)	2,466	.5920	.23	.39	.0650	.058	.89
Basic lead arsenate (neutral) (1-400)	2,384	1.6520	.29	.17	1.3400	.17	.13
Calcium arsenate (2-50)	2,106	.5800	.23	.40			
Nearly Mature Caterpillars							
Lead hydrogen arsenate (acid) (2-50)	383	5.7350	5.10	0.90	0.4700	0.23	0.49
Lead hydrogen arsenate (acid) (1-50)	803	4.3025	2.19	.51	.6300	.23	.36
Lead hydrogen arsenate (acid) (1-100)	565	4.7832	1.73	.36	1.1200	.12	.11
Lead hydrogen arsenate (acid) (1-400)	586	5.0720	.64	.13	2.0100	.17	.09
Lead hydrogen arsenate (acid) (1-800)	556	5.0540	.63	.12	2.8150	.23	.08
Lead hydrogen arsenate (acid) (1-1,200)	513	4.2080	.63	.16	2.8840	.23	.08
Basic lead arsenate (neutral) (2-50)	287	3.2800	1.15	.35	1.4030	.75	.53
Basic lead arsenate (neutral) (1-50)	455	3.7950	1.04	.28	1.6300	.58	.35
Calcium arsenate (2-50)	185	3.8950	3.22	.83	.5400	.34	.64
Calcium arsenate (1-50)	705	5.8760	1.90	.32	1.0480	.46	.44
Calcium arsenate (1-400)	532	4.6900	.63	.14	2.2700	.35	.15
Calcium arsenate (1-800)	152	1.4200	.17	.12	3.9783	.40	.11

A comparison of the relative time required to kill the small larvae and the nearly mature caterpillars, as indicated in Table VI, shows that although a higher percentage of the latter dropped in the early days of the test, it required a longer period to kill all of the larger forms.

Chemical Analysis. After the collection and drying of the poisoned caterpillars and the excrement from these various tests, a chemical analysis of representative material from each was made to determine the amount of arsenic present. These determinations are included in Table V.

For convenience in making comparisons the results of the chemical analysis are calculated in milligrams contained in the amount of sample taken and also the equivalent amount on basis of a one-gram sample.

Discussion of Results. These results throughout show consistently a higher arsenic content in the tissue and a lower arsenic content in the corresponding excrement with lead hydrogen arsenate as the spray than with either basic lead arsenate or calcium arsenate. Calcium arsenate comes second in this comparison, while basic lead arsenate shows the

TABLE VI. COMPARATIVE RESULTS AND RELATIVE KILLING EFFICIENCY OF ARSENATES

Kind and strength of solution	Number of days after being introduced that first caterpillars died		Percentage of caterpillars dead first day of drop		Total number of days to kill		Approximate amount of total arsenic devoured per 1,000 caterpillars		Ratio arsenic pentoxid in tissue is to arsenic pentoxid in excrement	
	Small caterpillars	Mature caterpillars	Small caterpillars	Mature caterpillars	Small caterpillars	Mature caterpillars	Small caterpillars	Mature caterpillars	Small caterpillars	Mature caterpillars
							mg.	mg.		
Lead hydrogen arsenate (2-50)	0	0	4.5	6.36	4	5	.....	11.815	.....	1-0.5440
Lead hydrogen arsenate (1-50)	0	0	2.94	2.74	4	5	.....	7.395	.....	1- .7058
Lead hydrogen arsenate (1-100)	.....	0	.....	8.25	.....	6	.....	3.995	.....	1- .3055
Lead hydrogen arsenate (1-400)	1	0	.46	.50	7	9	.1595	1.870	1-1.2100	1- .6900
Lead hydrogen arsenate (1-800)	1	0	1.58	1.08	12	8	.1633	1.700	1-1.3888	1- .6660
Lead hydrogen arsenate (1-1,200)	1	0	1.55	.68	13	14	.1519	2.040	1-1.6660	1- .5000
Basic lead arsenate (2-50)	0	3	2.17	26.65	5	7	.3911	.486	1-2.3230	1-1.5100
Basic lead arsenate (1-50)	0	3	1.52	18.00	6	7	.4860	5.355	1-1.7650	1-1.2500
Basic lead arsenate (1-400)	1	.....	.34	.....	14	.....	.1139	.....	.....	.....
Calcium arsenate (2.50)	0	0	3.28	26.53	5	5		.....	.....	.....
Calcium arsenate (1-50)	.....	0	.....	12.56	.....	5	.....	.....	.....	.....
Calcium arsenate (1-400)	.....	1	.....	6.13	.....	5	.....	.....	.....	.....
Calcium arsenate (1-800)	.....	1	.....	1.17	.....	7	.....	.....	.....	.....

smallest amount of arsenic content in the tissue, most of the arsenic eaten being found in the excrement, having passed through the intestinal tract unchanged.

A further study of the ratio of arsenic in the tissue to that contained in the excrement brings out some very interesting facts. In Tables V and VI with "nearly mature caterpillars," we note for lead hydrogen arsenate (2-50) that there was found 0.90 mg. of arsenic pentoxid per gram of tissue as compared with .049 mg. of arsenic pentoxid per gram of excrement, or a ratio of 1 to 0.544; in the calcium arsenate (2-50) there was 0.83 mg. per gram of tissue and 0.64 mg. in the excrement, or a ratio of 1 to 0.70; in the basic lead arsenate (2-50) there was 0.35 mg. per gram of tissue and 0.53 mg. in the excrement, or a ratio of 1 to 1.51. This ratio varies somewhat in the weaker strengths, but is consistent throughout, in that the amounts of arsenic are higher in the tissue and lower in the excrement in the relative order noted above.

This may be explained as being due to the relative stability of the three salts, since lead hydrogen arsenate and calcium arsenate are comparatively unstable compounds and would probably react more readily with the body juices, permitting a large amount of the arsenic to be assimilated and therefore retained within the tissue. The basic lead arsenate, on the other hand, is a very stable salt and would probably pass through the body comparatively unchanged, so that more arsenic would be found in the excrement than in the tissue.

These results indicate that the lead hydrogen arsenate is the best spray for rapid effective killing since a larger quantity of the poisonous element is assimilated by the caterpillar than of either of the other types. Assuming that the lead hydrogen arsenate approximates closely an efficient insecticidal spray and calculating from the figure obtained as given in the above tables at the dilution 1 to 400, we may generalize as follows relative to the specific amount of arsenic pentoxid necessary to kill a certain number of caterpillars: It required approximately 0.1595 mg. of arsenic pentoxid to kill 1,000 of the small tent caterpillars and 1.87 mg. to kill a like number of the nearly mature larvae. It is also interesting to note that, although a large percentage of the basic lead arsenate passes through the intestinal tract, the total amount of arsenic pentoxid devoured is about the same as for lead hydrogen arsenate—namely, 0.1139 mg. for 1,000 caterpillars. It is supposed from the data, therefore, that it takes approximately the same quantity of arsenic, whether from lead hydrogen or basic arsenate, to kill equal numbers of caterpillars, but the amount varies greatly, depending upon the size of caterpillars used. (See Table VI.)

SUMMARY

(1) Lead hydrogen arsenate has a higher killing efficiency at a given dilution than either calcium or basic lead arsenate.

(2) It requires a longer period of time to kill the nearly mature caterpillars than the small forms.

(3) All of the arsenic devoured by the insects in feeding upon sprayed foliage is not assimilated, but a portion passes through the intestinal tract in the excrement. The percentage of the arsenic assimilated de-

pends upon the arsenate used; lead hydrogen arsenate was assimilated readily and most of the arsenic was retained in the tissue, while much of the basic lead arsenate was found in the excrement.

(4) It requires approximately 0.1595 mg. of arsenic pentoxid to kill 1,000 small tent caterpillars, and approximately 1.84 mg. of arsenic pentoxid to kill 1,000 nearly mature tent caterpillars, irrespective of the particular arsenate used as a spray.

(5) A dilution of 1-400 of lead hydrogen arsenate proved a satisfactory killing dosage for the very small caterpillars.

PHYSICAL PROPERTIES OF THE SPRAY MATERIAL AND OF THE SPRAY SOLUTION

INTRODUCTION

The results of the investigations of 1915 and 1916 indicate the relative toxic values and killing efficiency of the various types of arsenates. Studies in the department of Agricultural Chemistry on the commercial lead arsenates in general use indicate that they are uniformly a high-grade product approximating in composition the pure acid lead arsenate form and carry a low percentage of soluble arsenic. Considered chemically, therefore, as a poison agent they should be approximately of equal value and equally safe to use.

A closer study of the report reveals a very interesting fact. This is indicated in Table VI and forms the basis for the past three seasons' major investigation.

In our laboratory tests of 1916 a very satisfactory killing efficiency was obtained with the acid lead arsenate against very small caterpillars at a dilution of 1 pound of arsenate to 400 gallons of water. Theorizing that a newly hatched codling-moth larva is no more resistant to poison than is a young tent caterpillar leads to the conclusion that we may be using our arsenate of lead in more concentrated form than is necessary. Our standard dilution in the field is 2 pounds to 100 gallons, or eight times the theoretical killing dosage of 4 to 100. Allowing for the natural factors which make it impossible to achieve ideal results under field conditions, theoretically 1 pound of arsenate to 100 gallons of solution should afford efficient control. This dilution of 1 to 100 represents four times the theoretical killing dosage necessary. In spite of this many growers feel that sufficient additional protection is obtained in the late summer applications for the codling-moth to warrant the additional expense of using 4 to 6 pounds of arsenate to 100 gallons.

A careful analysis of this apparent discrepancy warrants the contention that this condition may be due to physical causes rather than chemical. The amount of poison present in the solution is apparently more than sufficient; possibly it is not one hundred percent effective, due to physical defects: (1) In method of application. (2) In the spray material. (3) In the spray solution.

Recent developments in spray nozzles, combined with improved spray outfits of greater capacity, have marked a distinct advance in our methods of application.

Discussion of the investigation of spray practices and of comparative value of methods of application is taken up in Oregon Agricultural College Experiment Station Bulletin 171, Spray Gun versus Rod and Dust in Orchard Pest Control (May, 1920).

The investigation herein reported has to do with a study of the physical properties of the spray material and of the spray solution.

SPREADERS AND THE SPRAY SOLUTION

It is a matter of common experience that when examining a sprayed tree to check on the thoroughness of application one judges largely by the presence or absence of half circles and blotches of dried arsenate deposited more or less irregularly over the sprayed surface. These blotches are seldom of uniform thickness throughout, tending to a heavier coating along one margin. There are interspaces between the blotches apparently free of poison.

These physical defects would seem to limit the effectiveness of the poison spray. By improving the physical properties of the spray solution we should increase the effectiveness of the poison dosage. Our conception of an efficient spray solution is one which as it is applied allows the droplets to spread out and join one another in such a manner that upon drying the arsenate finally rests as an even, regular, inconspicuous covering affording a perfect and equal protection for every surface.

Our first endeavor, therefore, was to improve the physical properties of the poison spray solution by the addition of some substance that would assist in developing this desirable tendency of the droplets to spread and join one another. For convenience we have termed the substances added for this purpose "spreaders."

TESTS OF 1917

The work of 1917[5] with spreaders for arsenate sprays consisted of preliminary tests: (1) An attempt to correlate certain physical tests and establish principles for guidance in choosing suitable materials for use as spreaders. (2) The effect obtained by the addition of a few promising materials to the poison spray solution.

Early attempts to correlate the factors of surface tension and specific gravity failed to yield any definite data. This failure is largely accounted for in the published work of Cooper and Nuttall[6]. The theory of the wetting power of the solution explained much, and attempts to correlate the values of our possible spreaders were undertaken in 1918 and developed in 1919. See page 39.

Suspension Tests

The ability of a solution to hold arsenate in suspension, while not necessarily a definite criterion as to its value as a spreader, does indicate a physical quality in the solution much to be desired in a spreader.

The materials tested, dilutions used, and results of the tests are included in Table VII.

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[5]Lovett, A. L. 1918. Spreaders for Arsenate Sprays. Jour. Econ. Ent. XI, p. 66.

[6]Cooper and Nuttall. 1915. The theory of wetting and the determination of the wetting power of dipping and spraying fluids containing a soap basis. Jour. Agri. Science VII, p. 219.

One thousand cubic centimeters of each solution was taken, cylinders of uniform size and 1000 c.c. capacity being used, and to each solution was added 5 grams of acid lead arsenate. The cylinders were thoroughly and uniformly agitated and the arsenate allowed to settle. Readings were made at the end of 5 minutes, 10 minutes, 2 hours, and 6 hours.

TABLE VII. SUSPENSION TESTS WITH SPREADERS 1917

Material	Dilution*	Readings of settled arsenate				Remarks
		5 min.	10 min.	2 hrs.	6 hrs.	
Sage tea	1-1000	1 cc.	1.2 cc.	3.6 cc.	6 cc.	Good
Sage tea	5-1000	.7 cc.	.9 cc.	2.8 cc.	4.8 cc.	Very good
Glue	1-1000	.8 cc.	1 cc.	3.4 cc.	6 cc.	Good
Glycerine	5-1000	.6 cc.	.9 cc.	4.2 cc.	7.1 cc.	Good
Gelatine	1-1000	.5 cc.	.6 cc.	2 cc.	3.1 cc.	Excellent
Sugar	5-1000	7.7 cc.	9 cc.	All down		More rapid than water
Honey	5-1000	3.8 cc.	4 cc.	8 cc.	All down	Poor
Gum tragacanth	1-1000	6.8 cc.	All down			No good
Fish oil soap	1-1000	2.5 cc.	3 cc.	4.8 cc.	All down	Material flocculent
Casein lime	1-1000	1 cc.	1.6 cc.	3.2 cc.	5.8 cc.	Good
Resin soap	5-1000	3 cc.	3.8 cc.	5 cc.	All down	Poor
Water	-	6 cc.	8 cc.	All down		

* The dilution figures refer to the number of grams or cubic centimeters of material to 1000 c.c. of water; 5 grams of acid lead arsenate was added to each solution.

Some of these materials were run a second and even a third time, but with little variation in the general results. The sugar behaved very peculiarly in actually precipitating the arsenate. The gum tragacanth did not go into solution and itself settled down to the lower two-thirds of the cylinder.

Tests for Burn

A test of the solutions on bean foliage was made, primarily for burn, but incidentally it gave an indication of great promise for two of the materials as spreaders. Twenty-five pots of uniform size and containing similar soil were planted to an excess of common navy beans, and placed in the greenhouse to grow. When the plants had attained a fair size, ten pots were thinned down to a single uniform bean plant and ten were thinned to two plants. In the following experiment the single plants were used in reduced sunlight, while those with two plants were used in direct sunlight. The plants were sprayed on November 14 and observations on burn were made November 19, 24, and 29. The arsenate in all cases was used at a strength of 4.8 grams to 1000 c.c. of solution. The materials used and final results are contained in Table VIII.

TABLE VIII. RECORD OF BURN

Materials	Dilution	November 19		November 24		November 29		Remarks
		Direct sun	Reduced sun	Direct sun	Reduced sun	Direct sun	Reduced sun	
Fish oil soap	1-1000	Medium urn	Slight	No change	No change	Serious	Fair burn	Not suitable
Glycerine	5-1000	Slight	General slight	General	No change	Not bad	No change	Questionable
Glycerine	10-1000	Considerable	No burn	Serious	No change	Serious	Serious	Not safe
Glue	1-1000	Medium burn	Medium burn	No change	No change	Fairly bad	Not serious	Questionable
Gelatine	1-1000	Slight	No burn	No change	No change	Slight	Trace	Good
Sage tea	5-1000	No burn	No burn	No burn	No change	No burn	No burn	Excellent
Sage tea	10-1000	Slight	No burn	Same	No change	Trace	No burn	Excellent
Caseinlime	5-1000	Trace	No burn	No change	No change	Trace	No burn	Excellent
Limesulfur	10-1000	No burn	No burn	Slight	No change	Fair	Slight	Questionable
Limesulfur	20-1000	Scattering	Large spots scattering	Spreading bad	No change	Serious	Fairly bad	Not safe
Check		Considerable	Small, general	Spreading, general	No change	Serious	Considerable	

The two materials which gave the least burn, sage tea and the casein-lime mixture, likewise approximated the ideal sought for in a spreader. The casein-lime solution, particularly on the bean foliage, spread out evenly and uniformly, depositing the arsenate in a smooth, even, inconspicuous coating. A similar test of these two materials as spreaders on the foliage of strawberry was made and gave most satisfactory results.

The two materials are prepared as follows:

Sage Tea. The material referred to here as sage tea is the solution obtained by steeping one pound of cut-up leaves and stems of our common prairie sage bush of Oregon (Artemisia tridentata Nutt.) in one gallon of water. The water is brought to a boil, removed from the fire, the sage added and the vessel covered and allowed to stand for 12 hours or more, when the liquid is drawn off. This sage tea is a brown, oily, emulsion-like solution. The oils and other ingredients present have not been determined but are probably similar to those as given by Robak[7] for white sage (*Artemisia frigida* Willd).

While these preliminary tests of sage tea as a spreader were encouraging, later trials proved it to be of questionable value on the waxy surface of apple fruit. Excellent on foliage, its use for our purpose was too restricted because it was not a good wetting agent for use on fruit.

Casein-Lime Mixture. The suggestion of the casein-lime mixture was obtained from an abstract of an article appearing in the Agricultural Gazette of New South Wales, XXIV, pt. 10, p. 868, on spreaders for Bordeaux mixture. In these early tests the material was prepared as suggested there, the procedure being as follows:

To 3.5 grams of quicklime was added 1.5 grams of powdered casein. This material was ground in a mortar to a homogeneous mass. The amount to be added to the solution was then weighed out and by small additions of water and much stirring finally rendered to a thin paste and then added to the general solution. Considered chemically we may term this calcium caseinate, a colloidal solution, probably of variable composition.

The very nature of this material, its cheapness, the small amount required, and apparently desirable qualities have led us to give this material a place of first rank in our subsequent studies of spreaders.

In laboratory tests it was found that equally good results were secured with the mixture when it was prepared from the commercial hydrated lime. In subsequent tests, therefore, unless otherwise indicated the casein-lime mixture is referred to as calcium caseinate and is prepared as follows:

CALCIUM CASEINATE

Powdered casein .....1.5 parts
Hydrated lime .....3.5 parts
Mix thoroughly, then reduce to thin paste by small additions of water and much stirring.

TESTS OF 1918

Laboratory tests with possible spreaders as carried forward in 1917 were continued in 1918.

[7]Robak, F. 1906. U. S. Dept. of Agric. Bur. Plant Ind. Bul. 235, p. 21.

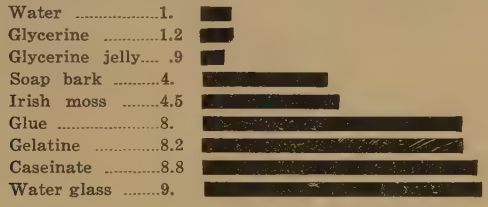
Suspension Tests

A test of the comparative value of various promising spreaders in improving the suspension properties of the spray solution was performed fundamentally as in the similar experiments last season. Graduates of 1000 c.c. capacity were used and a five-gram sample of calcium arsenate was added to each solution.

The materials used as spreaders were added at the rate of .5 gram, in the case of solids, to the 1000 c.c. of solution and at the rate of .5 c.c. in the case of liquids. Readings were made at the end of 2, 10, 25, and 75 minutes. The solutions were agitated a second time and readings made at the end of 10, 40, and 90 minutes.

The results of these tests have been summarized and prepared as a graph, using water as the unit.

FIG. 3. RELATIVE SUSPENSION VALUES OF SPREADERS, 1918



Discussion of Results. Glue, gelatine, caseinate, and water-glass show very good values as suspensoids. In subsequent tests with those materials which are dissolved in warm water, it was found that temperature plays an important part in determining the effectiveness of the materials. High temperatures decrease the value of glue and gelatin.

The tests were repeated increasing the amount of the suspensoids to 1 gram and 1 c.c., or twice the previous amount. No marked differences were observed except in the case of glue, where the value was materially improved at the increased strength.

TABLE IX. SPREADER TESTS IN LABORATORY, 1918

Material	Dilution to 1000 c.c.	Cabbage	Oil paper	Paraffin paper	Remarks
Water	.....	Very poor	Poor	Poor	
Glycerine	1 c.c.	Very poor	Very poor	Very poor	Poorer than water; no value as a spreader, burns foliage.
Water glass	1 c.c.	Very poor	Poor	Poor	No value, slightly better than water.
Caseinate	1 g.	Excellent	Fair	Good	Shows to particular advantage on cabbage foliage.
Soap bark	1 g.	Excellent	Good	Very good	Not equal to caseinate on cabbage, better on paraffin.
Irish moss	1 g.	Poor	Poor	Fair	About same as water glass.
Gelatine	1 g.	Excellent	Very good	Very good	Superior to either caseinate or soap bark.
Glue	1 g.	Fair	Good	Good	Uniformly good, resembles but by no means equals gelatine.

Spray Tests

Tests of these materials as spreaders on different surfaces were next performed, using the materials at a strength of 1 gram or 1 c.c. to 1000 c.c. The surfaces used were cabbage foliage, oil paper, and paraffin paper. The tests were made in three ways: droplets from the end of a stirring rod; droplets from a 1 c.c. pipette; and applied with an atomizer as a fine, misty spray. The results are tabulated in Table IX.

Field Tests with Spreaders, 1918

Preliminary tests of promising materials were made using a single bearing apple tree for each material. The substances tested and results are tabulated in Table X.

TABLE X. FIELD TEST OF PROMISING SPREADERS, 1918

No.	Material	Amt. in 10 gal.	Effect as spreader		Remarks
			On apple fruit	On apple foliage	
		oz.			
1	Soap bark	8	Excellent	Excellent	Wets beautifully and spreads evenly as inconspicuous coat on both fruit and foliage.
2	Sage tea	8	Poor	Fair	Only fair on foliage and failure on fruit.
3	Gelatine	1.75	Excellent	Excellent	Approximates No. 1 though not quite equal to it.
4	Glue	1.75	Fair	Good	Very good spread and wet on foliage, only fair on fruit though of some advantage.
5	Glycerine	8	Fair	Good	Approximates No. 4 but not equal to it as spreader. Of no value, also causes serious burn after a few days.
6	Gum arabic	1.5	Negative	Negative	Of no value as spreader on foliage or fruit.
7	Calcium caseinate	1.5	Good	Excellent	Ideal on foliage, very good on fruit, though wetting and spread here not equal to that on foliage or to No. 1.
8	Sugar	8	Negative	Negative	No value.
9	Soap bark	8	Excellent	Excellent	Approximates No. 1. Differs in preparation. (See p. 25.)

Preparation of Spreaders

Some of the more promising of these materials were used in subsequent tests. A brief discussion of what they are and the methods of preparation for use is given.

No. 1. Soap bark, saponin (*Quillai saponiaria*) is a commercial bark obtained from the inner layers of bark of an evergreen tree of Chili. Saponin is also obtained from a variety of different sources, though probably no other bark or nut yields a material showing so high a soapy content. Very small amounts of soap bark in a solution give it a distinct soapiness, and when the solution is agitated a heavy semi-permanent suds is formed.

In these earlier tests the bark itself was used. It was broken into small bits and added to water at the rate of 4 ounces of the bark to 1 quart of water. In the first test the bark was added to cold water and allowed to soak for twenty-four hours. For use in the test, 8 ounces of the liquid so obtained was added to the 10 gallons of spray solution.

No. 2. Sage tea was prepared as before, see page 22. Eight ounces of the tea was added to the 10 gallons of spray.

No. 3. The gelatine used was ordinary sheet gelatine, 1.75 ounces being dissolved in a small amount of warm water and added to the 10 gallons of spray solution.

No. 4. The glue used was ordinary commercial brown (sizing) glue, 1.75 ounces dissolved in a small amount of warm water being added to 10 gallons of spray solution. Subsequent tests indicate that hoof glue is much superior to brown glue as a spreader.

No. 5. The glycerine used was ordinary commercial glycerine, 8 ounces to the 10 gallons of spray solution.

No. 6. Commercial gum arabic was dissolved in warm water and added at the rate of 1.5 ounces to the 10 gallons of solution.

No. 7. See preparation of caseinate on page 22. Hydrated lime was used for mixing with the casein in these tests, the mixture being used at the rate of 1.5 ounces to the 10 gallons.

No. 8. Eight ounces of cane sugar was added direct to the 10 gallons of spray solution.

No. 9. The soap bark was used as in No. 1, except that bits of bark were added to a quart of water and boiled fifteen minutes. Eight ounces of the resulting fluid was added to the spray solution.

Remarks on Results. Soap bark in these tests showed promise as a spreader. It had exceptional wetting ability both on apple foliage and on the fruit. The apples at this time were small, pubescent, with little indication of the waxiness so evident in the mature fruit.

Sage tea in these and subsequent tests not reported proved of so little value or promise as a spreader as to be discarded from further field tests.

Gelatine has great possibilities as a spreader for arsenate sprays. The results of other investigators place this material in the first rank because of the great wetting and adhesive properties its presence adds to the spray solution even when present in small quantities. Failure to procure a sufficient quantity for field tests prevented use of this material in the more elaborate field experiments which its qualities warrant.

Glue has possibilities as a spreader. To be of value considerable quantities are required. It acts much like gelatine, but is by no means equal to it.

Glycerine, while possessing fair wetting properties, causes burn and was therefore discarded. Gum arabic and sugar proved worthless and were likewise discarded from further tests.

Calcium caseinate, while not equal in a comparative test on the pubescent fruit to some of the other substances, has merit as a spreader. It has an advantage in cheapness, availability, compatability in most spray combinations, and in ease of preparation. For these reasons it was given first rank in our subsequent tests and experiments.

These preliminary tests were followed by actual comparative tests of spreaders in the solution in commercial orchard spraying experiments for codling-moth control. These commercial orchard tests were carried

forward during 1918 and 1919. One orchard was sprayed in 1918 and two orchards were included in our experimental tests in 1919. These field experiments also included comparative tests of commercial arsenates of variable physical qualities. A discussion of these experiments and results follows.

Field Spray Tests in Commercial Orchard, 1918

In this series are included: (1) Efficiency tests of the spray solution with and without spreaders. (2) Comparative tests of efficiency of the spray material; namely, calcium vs. lead arsenate, paste vs. powdered lead arsenate, and average commercial lead arsenates vs. brands having more than the average qualities from a physical point of view, i. e., fineness and uniformity of division of particles.

Eight materials were used. Two hundred gallons of each solution was applied throughout the seasonal schedule of codling-moth applications. Four varieties of apples were represented, including Grimes, Wagoners, Ortleys, and Newtowns. Lime sulfur in the usual proportions was added in the first two applications, except on the Grimes where it was omitted in the "30-day" spray.

The spray was applied with duplex-power orchard sprayers carrying rods and a Y fitted with small disc nozzles. The machines carried a pressure of 175 to 210 pounds and delivered a uniformly fine, misty spray. Regular orchard help handled the spray rods throughout the season, and no especial effort was made to get a thorough application except for an occasional admonition by the orchard foreman such as might occur in regular spraying.

Four regular applications were made: the "calyx" spray, May 9 and 10; the "30-day" spray, June 10-11; the "July" spray, July 28-9; and the "August" spray, September 2-4. A second calyx spray was required on the Wagoners due to a later blossoming of the terminal fruit buds after the main blossoming period. This second calyx spray was applied to the Wagoners on May 24. The Grimes did not receive the September 2-4 application as picking had begun on this variety at that time.

No trees were retained as a check without spray. The high percentage of worms in some of the sprayed blocks and the fact that orchards here and there in the Valley ran from 30 to 80 percent worms warrants the assumption that all the sprays were of some value. The brands and dilutions used, trees counted, and the results are included in Table XI.

Remarks on Table XI. The percentage of worms present in all the plots is entirely too high. The season of 1918 was a particularly difficult one for effective worm control. As late as August 25 an infestation of 2 percent is a liberal estimate for the orchard. Late emerging moths were responsible for a heavy egg deposition from about August 25 to September 8. While we anticipated this outbreak in time and recommended a protecting spray, a delay of 6 days occurred in its application due to the orchard teams and men being unavoidably occupied with other duties. Eggs were hatching and numerous fresh entrance holes were observed while the spraying was under way.

TABLE XI. SPREADER AND ARSENATE TESTS IN COMMERCIAL ORCHARD, 1918

	Material	Form	Dilution	Spreader	Trees counted	Apples counted							Remarks
						Total	Clean	%	Wormy	%	Stings	%	
1	*Kedzie formula	Home-made	See note	None	2	565	461	81.6	95	16.8	9	1.6	Did not stay in suspension well, granular. Poor spread.
2	Average lead arsenate	Powder	4-200	None	6	1053	806	76.5	226	21.4	21	2.1	Stayed in suspension well, blotchy spread as with any average arsenical solution.
3	Average lead arsenate	Powder	2-200	Caseinate	7	3435	3155	91.8	211	6.1	69	2.1	Calcium caseinate, 12 oz. to 200 gal. Gave excellent cover spray on foliage and fruit.
4	Superior lead arsenate	Powder	4-200	None	8	3003	2601	86.6	351	11.7	51	1.7	Excellent suspension, good spread, fair cover.
5	Superior lead arsenate	Powder	2-200	Caseinate	7	2767	2296	83.0	401	14.5	70	2.5	Calcium caseinate, 12 oz. to 200 gal. impaired rather than helped. Some reaction was evident.
6	Commercial calcium arsenate	Powder	6-200	None	4	1115	989	88.7	106	9.5	20	1.8	Added 2 lbs. hydrated lime to each lb. of calcium arsenate used. Suspension good.
7	Commercial calcium arsenate	Powder	4-200	None	8	3560	3242	91.0	259	7.3	59	1.7	Same as above. Spread in both cases average of ordinary spray solution.
8	Commercial lead arsenate	Paste	8-200	None	5	1083	812	74.9	249	22.9	22	2.2	Poor suspension, granular.

* This home-prepared arsenical, known as the Kedzie formula, was prepared and diluted as follows: White arsenic, 1 pound; salsoda (crystal), 4 pounds; boiled together in 1 gallon water for 20 minutes. For 200-gallon spray tank 1 gallon solution and 16 pounds freshly slaked lime were used.

The Kedzie home-made preparation gave very good results, comparatively speaking, as it did not show particularly promising properties. The fact that the tests with this material were confined to Wagoners, a variety not particularly susceptible to codling-moth injury, may account for the reasonably favorable showing.

Tests No. 2 and No. 3 represent a good average commercial powdered lead arsenate. No. 2 is in the usual dilution of 4 pounds to 200 gallons; No. 3 is the same lead at one-half the usual dilution, or 2 pounds to 200 gallons, with the addition of a spreader. The difference in favor of a spreader is very striking. At the usual strength we have 21.4 percent worms. Using only one-half as much poison, with a spreader, the infestation is 6.1 percent or an improvement in control of nearly two-thirds. Plots No. 4 and No. 5 represent a superior commercial powdered lead arsenate; No. 4 at the usual dilution of 4-200; No. 5 at one-half the usual dilution, or 2 to 200 plus a spreader. The interesting fact here is that the difference is in favor of No. 4, the usual dilution without the addition of a spreader. No. 4 shows 11.7 percent worms; No. 5 shows 14.5 percent. This apparent discrepancy in the use of a spreader is explained in that this particular commercial arsenate has an organic spreader incorporated with the regular material. This lead spread, wet, and adhered well, therefore, without the addition of a spreader, and the heavier dosage represented in No. 4 was sufficient to give slightly superior control. In fact, field observations and communications from the company warrant the assumption that a caseinate spreader is of little or no value in the commercial leads where an organic spreader is already present.

Plots No. 6 and No. 7 represent a good commercial brand of nearly pure calcium hydrogen arsenate with more than average physical qualities. The fact that the lower dilution represented in No. 7 gives as good and in fact slightly better control than No. 6 indicates that a strength of 4 pounds to 200 gallons is as high a strength as required for most effective control. It may also be noted that the control obtained with the calcium arsenate is superior to that obtained with the better grades of lead arsenate and nearly equal to that of an average lead with a spreader.

No. 8 represents a good commercial arsenate-of-lead paste. This shows the poorest control of all. From this and other tests not reported and from the findings of other investigators, we may conclude that: (1) The commercial lead arsenate pastes are not equal in physical properties to the better grade of lead arsenate powders. (2) The powders are vastly easier to get into solution in the spray tank than are the pastes. (3) Where, due to long standing or to freezing, a portion of the water is removed from the paste arsenate of lead, the physical properties are impaired. (4) Finally, it may be stated that unless one is near the point of manufacture, thus guaranteeing the receipt of freshly compounded and unimpaired paste, it is advisable to use the powdered form of arsenate spray material.

TABLE XII. MATERIALS, DILUTIONS, AND DATES OF APPLICATION, ORCHARD 1, 1919

Plot	Material	Spreader	May 8	June 5	July 2	July 28	Aug. 20
1	Superior lead arsenate	None	2-200	2-200	3-200	3-200	4-200
2	Superior lead arsenate	None	4-200	4-200	4-200	6-200	8-200
3	Superior lead arsenate No. 2	None	2-200	2-200	2-200	2-200	4-200
4	Superior lead arsenate No. 2	None	2-200	2-200	2-200	3-200	4-200
5	Superior lead arsenate No. 2	None	3-200	3-200	3-200	4-200	6-200
6	Average lead arsenate	None	4-200	4-200	4-200	4-200	4-200
7	Average lead arsenate	Caseinate	2-200	2-200	2-200	3-200	4-200
8	Average lead arsenate	Soap bark	2-200	2-200	2-200	3-200	4-200
9	Commercial calcium* arsenate	Caseinate	2-200	2-200	2-200	3-200	4-200
10	Commercial calcium* arsenate	Caseinate	4-200	4-200	4-200	6-200	8-200

* Two pounds of hydrated lime was added for each one pound of arsenate in all cases where calcium arsenate was used.

FIELD TESTS IN COMMERCIAL ORCHARDS, 1919

The field spraying experiments of 1919 were similar to those of last season though on a more elaborate scale. Two orchards were included in the tests. The same orchard as used last year was included again and another smaller orchard was used for a coordinated series of experiments.

Spray Tests in Orchard 1

Orchard 1 designates the orchard used last season. The experiments include comparative tests of spreaders; calcium vs. lead arsenate, and average vs. superior brands, considered from a physical point of view.

A total of ten tests was included. The same outfits and practically the same men as last year were employed. In an effort to avoid the losses of last year more time and care were taken in applying the spray and nearly three times as much solution was used per application as last year. The spraying could be termed above the average in thoroughness.

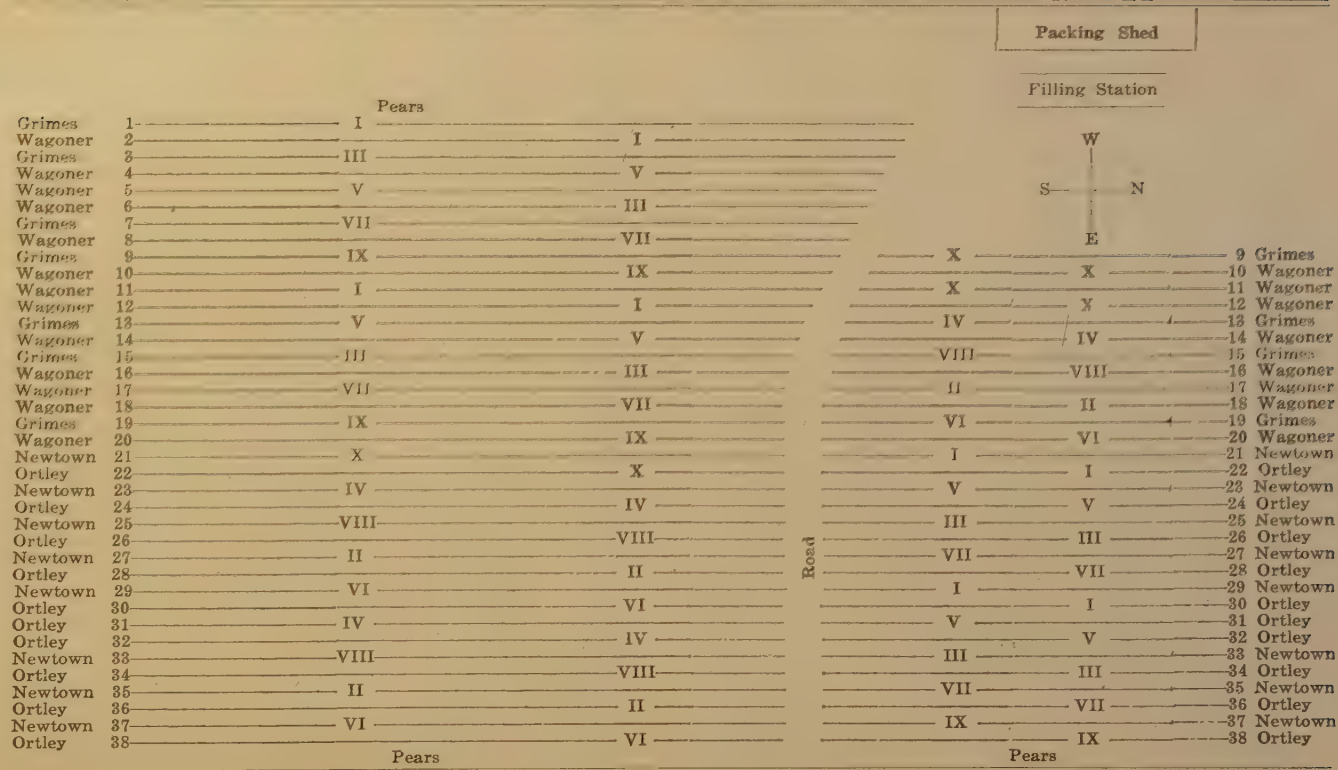
The seasonal variations of the codling-moth were not so erratic as in 1918, and life-history records and the proper timing of sprays were comparatively simple matters. Five worm sprays were applied, three for the first generation and two for the second. The materials used, dilutions, and dates of application are included in Table XII.

Check trees were, supposedly, maintained, but unfortunately all received at least two applications of spray during the season. From counts in adjacent orchards and considering the high percentage of worms in the check rows in orchard 2 it is reasonable to suppose the opportunities for worm injury in this orchard were fair.

All four varieties, Grimes, Wagoners, Ortleys, Newtowns, were included in each test. A plot of the orchard is given to show the general arrangement of the varieties and of the various plots as sprayed.

Counts were made at thinning time and at picking time. At thinning time the apples on the ground were counted; the thinners were

FIG. 9. PLOT OF ORCHARD 1, 1919, SHOWING VARIETIES AND DISTRIBUTION OF PLOTS



cautioned to thin off any wormy fruit. Representative trees of each variety in each plot were counted at this time. At picking time, as a rule, three trees were counted in each variety in the plot, or three trees in each of 4 or 6 rows. Table XIII gives the results of these counts.

TABLE XIII. COUNTS OF WORMY APPLES AT THINNING TIME AND PICKING TIME ORCHARD 1, 1919

Thinning Time

Plot	Trees counted	Total	Clean	Number wormy	Calyx	Percent wormy	Fruit worms
1	9	4355	4304	5	0	.1+	44
2	16	4625	4440	5	0	.1+	180
3	12	3335	3217	17	5	.5+	101
4	12	4653	4430	19	2	.36+	204
5	8	3353	3248	25	13	.74+	80
6	15	5147	4986	11	1	.21	160
7	10	3391	3281	26	11	.76	84
8	14	5129	4894	8	0	.15	227
9	9	4113	3897	9	1	.21	207
10	12	4476	4322	5	1	.11	149

Picking Time

Plot	Trees counted	Total	Clean	Number wormy	Calyx	Stem	Stings	Percent wormy	Percent stings	Fruit worms
1	15	6776	6598	55	3	4	38	.81	.56	84
2	16	6127	5975	13	4	0	36	.21	.58	103
3	16	5171	4984	55	12	2	28	1.06	.54	104
4	14	3489	3293	53	3	0	51	1.51	1.47	92
5	18	6739	6539	65	14	4	57	.96	.83	78
6	18	6549	6328	62	4	3	56	.94	.85	103
7	16	6440	6177	80	15	6	61	1.24	.94	122
8	16	5794	5591	31	4	0	35	.53	.91	117
9	17	6499	6172	104	6	19	17	1.6	.26	206
10	12	3693	3547	39	9	0	42	1.05	1.13	67

Remarks on Table XIII. The variations in the percentage of worms in the different plots included in the experiment are so slight as to be within the scope of experimental error, and comparative results are practically nil.

The broods of codling-moth were fairly clearly defined in the season of 1919, permitting the timing of the applications of spray with sufficient accuracy to obtain maximum effectiveness in control. The applications were put on with unusual thoroughness. These two factors account in a large measure for the uniformly good results in control obtained.

Appearance of Sprayed Fruit. In checking on the physical properties of the various spray materials and solutions as affording a perfect protection for the surface of the sprayed fruit, careful field notes were made on the sprayed fruit some two weeks subsequent to the last application of spray. The notes included appearance, comparative spread and adhesiveness, and general covering and protective qualities of the various materials.

Plot 1. Latimer's 4-200. Color, white; adhesiveness very good, no flakiness; covering conspicuous, blotchy, large blotches above, smaller below, deposit heavier at margin; interspaces not covered; some tendency to spread, but not marked. Plate I, Fig. 1.

Plot 2. Latimer's 8-200. Similar to No. 1. Blotches heavier; tendency to even thickness throughout with but little tendency towards

heavier deposit at margin; slight tendency to spread apparent. Plate I, Fig. 2.

Plot 3. Rex Nuform 4-200. Color grey; adhesiveness good; slight tendency to flakiness; covering conspicuous, blotchy, blotches not so heavy nor the margins so clearly defined as with No. 1; spread fair, interspaces showing evidences of some protective covering.

Plot 4. Rex Nuform 4-200. Same general remarks as for No. 3; tendency to waviness indicating spread. Plate I, Fig. 4.

Plot 5. Rex Nuform 6-200. Covering heavier; interspaces not so well protected. Similar to No. 2; slightly better spread; not quite so good adhesiveness. Plate I, Fig. 5.

Plot 6. Gliddens 4-200. Color grey white; adhesiveness fair, surface powdery; covering irregular, blotchy—some blotches large and indistinct; others small, heavy, clearly defined, with heavier deposit at margin; spread slight. Plate II, Fig. 6.

Plot 7. Gliddens 4-200 and caseinate. Color greyish; adhesiveness excellent; no tendency to flakiness; covering uniform, inconspicuous, smooth, thin, and even over entire outer and upper surface; tendency to blotchiness below, though blotches are indistinct and wavy; spread excellent, almost perfect protection. Plate II, Fig. 7.

Plot 8. Gliddens 4-200 and soap bark. Very similar in every way to No. 7; adhesiveness possibly not quite so good; tendency to waviness; spread slightly better. Plate II, Fig. 8.

Plot 9. Calcium arsenate 4-200 and caseinate. Color bluish; little tendency to blotchiness; heavy, even, practically perfect covering; some blotches below, indistinct; margins wavy, not clearly defined; good spread; fair adhesiveness, where coating is particularly heavy, with tendency to flakiness.

Plot 10. Calcium arsenate 8-200 and caseinate. Heavy conspicuous cover with characteristic heavy blotches, thick, close together, with tendency to run together; interspaces protected; strong tendency to flake off in center of heavier blotches; adhesiveness fair; spread very good. Plate II, Fig. 10.

Spray Tests in Orchard 2

The experiment in orchard 2 included tests of the efficiency of spreaders in the spray solution; the use of nicotine sulfate alone as a supplement to or in combination with lead arsenate for worm control; the value of the calyx application alone as against a full spray program omitting the calyx spray; and tests of magnesium arsenate, a new commercial material for codling-moth control. Tests were also made of the efficiency of the spray gun against the spray rod fitted with a Y and carrying disc or mistry nozzles as against the spray rod and Y fitted with clipper nozzles. One commercial brand of lead arsenate was used throughout.

Counts at picking time showed no marked variation in codling-moth control obtained by the different methods of application. No separate figures are given on this phase of the investigation. Because of the ease and rapidity of application, the spray gun was employed for the most part and gave excellent and satisfactory service.

The schedule of sprays, dates of application, materials used, are given in Table XIV.

Plate I. Appearance of sprayed fruit in commercial tests of physical properties of various leads and spreaders.
Fig. 1. Latimer's lead arsenate 4-200 alone. Fig. 2. Latimer's lead arsenate 8-200 alone. Fig. 4. Rex Nuform 4-200 alone. Fig. 5. Rex Nuform 6-200 alone.

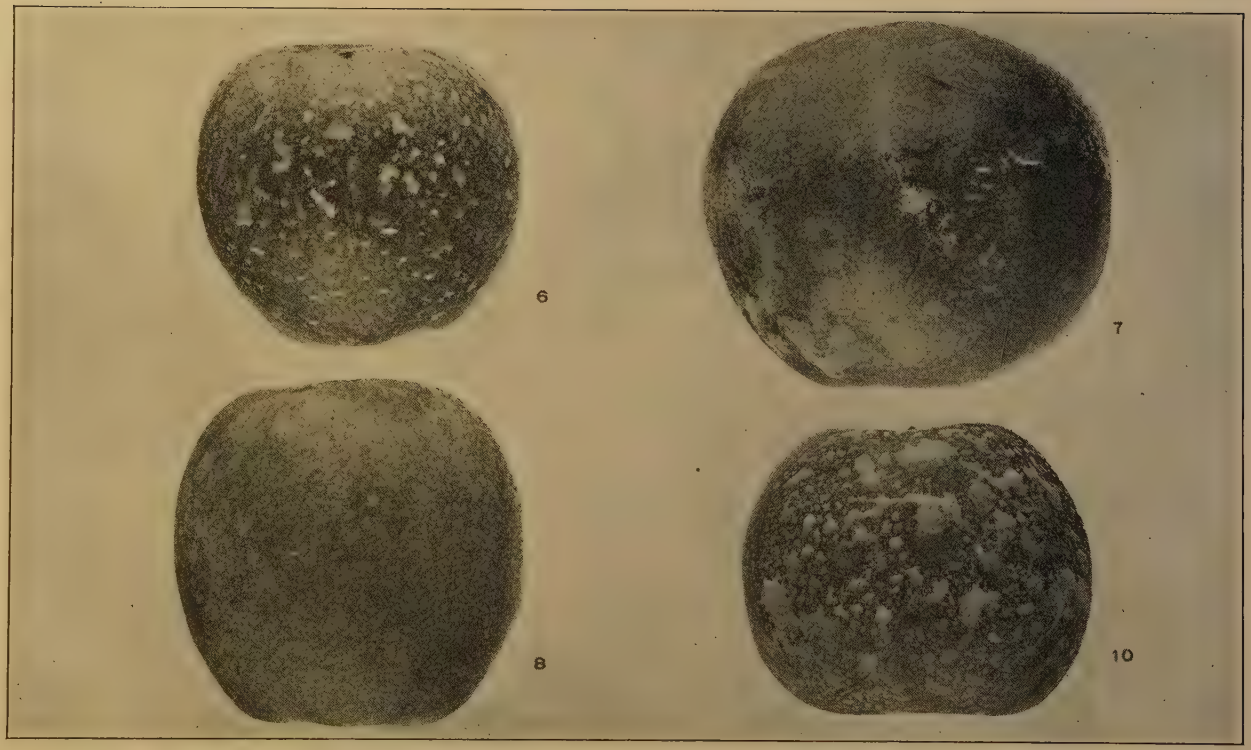


Plate II. Appearance of sprayed fruit in commercial tests of physical properties of various leads and spreaders.
Fig. 6. Glidden's lead arsenate 4-200 alone. Fig. 7. Glidden's lead arsenate 4-200 plus caseinate spreader. Fig. 8. Glidden's lead arsenate 4-200 plus soap bark spreader. Fig. 10. Sherwin-Williams calcium arsenate 8-200, plus caseinate spreader.

TABLE XIV. MATERIALS AND DATES OF APPLICATION IN ORCHARD 2, 1919

Plot	1st spray, May 8			2d spray, June 5			3d spray, July 1			4th spray, July 28			5th spray, August 20		
	Material	Dilution	Spreader	Material	Dilution	Spreader	Material	Dilution	Spreader	Material	Dilution	Spreader	Material	Dilution	Spreader
1	Lead arsenate	2-100	None	.....	.....	.....	.....	.....	.....	.....	3-100	.....	.....	4-100	.....
2	Lead arsenate	2-100	None	.....	.....	.....	.....	.....	.....	Black Leaf 40	1-1200	Fish oil soap 4-100	Do. No. 4	.....	Do. No. 4
3	Lead arsenate	2-100	1 gal. Misc. oil No. 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	Lead arsenate	1-100	1 gal. Misc. oil No. 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	Magnesium arsenate	2-100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	Lead arsenate	3-100	None	Calyx spray only—two applications to make application thorough											
7	Black Leaf 40	1-1200	Fish oil soap 4-100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1-800	.....
8	Lead arsenate	2-100	Fish oil soap 4-100	.....	.....	None	.....	.....	None	.....	.....	None	Do. No. 1 and Black Leaf 40	1-800	.....
9	Calyx spray	omitted	.....	Lead arsenate								.....	.....	.....	.....
				.....	2-100	None	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	Check														

Note: Blanks indicate materials and dilution of previous application continued.

In Table XV is given a summary of the season's results for the various plots and applications. Counts of wormy apples were made at thinning time, but as the infestation throughout was uniformly very low, though approximating the averages obtained at picking time, the figures for the two counts are combined and are included together in the table.

TABLE XV. RESULTS OF TESTS IN ORCHARD 2, 1919

Plot	Variety	Total apples	Wormy apples	Calyx worms	Stings	Percent wormy
1	Spitzenburgs	399	13	0	11	3.3
	Newtowns	761	8	0	8	1.0
2	Spitzenburgs	387	26	1	14	6.7
	Newtowns	630	5	0	4	.7
3	Spitzenburgs	491	11	0	5	2.2
	Newtowns	429	1	0	1	.2
4	Spitzenburgs	607	30	0	22	4.9
	Newtowns	718	8	0	8	1.1
5	Spitzenburgs	204	11	0	0	5.4
	Newtowns	557	6	0	5	1.1
6	Spitzenburgs	481	67	1	0	14.0
	Newtowns	990	31	0	0	3.1
7	Spitzenburgs	248	20	4	3	8.0
	Newtowns	1074	85	43	12	7.9
8	Spitzenburgs	67	1	0	1	1.5
	Newtowns	643	8	0	7	1.2
9	Spitzenburgs	117	5	1	1	4.2
	Newtowns	719	39	10	10	5.6
10	Spitzenburgs	414	291	158	0	70.2
	Newtowns	870	513	332	0	58.9

Remarks on Table XV. It is evident from a glance at the comparative percentage of worm infestation for the two varieties that the Spitzenburg is more susceptible to codling-moth attack than is the Newtown.

Plot 10 represents the check block of trees which did not receive an application of poison spray during the season. The worm infestation in this plot may therefore be considered representative of the natural codling-moth conditions in the orchard where undeterred by poison sprays. In addition to indicating the degree of control obtained in the various sprayed blocks we find the following points of interest. In the Spitzenburgs we have a total infestation of 70.2 percent worms. Of the total worms, 54.3 percent, or slightly more than one-half were calyx worms. In the Newtowns we have a total of 58.9 percent worms. Of the total worms 64.7 percent, or approximately three-fifths, are calyx worms. This percentage of calyx worms to total infestation tallies very closely with our counts and observations for a period of years in the various apple-growing sections of Oregon.

Note throughout the sprayed plots, with the exceptions of plots 7 and 9, the practically perfect control of calyx worms. This is likewise the case in orchard 1, indicating that a misty spray properly applied with gun or disc nozzle is thoroughly effective as a calyx application.

In plot 1 the standard lead arsenate spray of 2-100 was applied in the earlier applications, increasing the dosage to 3-100 in the early summer spray and to 4-100 for the late summer application. The percentage of worms for the Spitzenburgs and Newtowns was respectively 3.3 and 1.0 percent. In plot 2 where the same treatment was used for the earlier sprays, changing in the two later applications to nicotine sulfate plus

fish-oil soap as a spreader, for the two varieties we have 6.7 and .7 percent worms respectively.

In plots 3 and 4 miscible oil No. 2 at the rate of 1 gallon to the 100 gallons of spray solution was added as a spreader. In plot 3 the lead arsenate was used throughout the seasonal schedule at the standard dilution of 2-100. In plot 4 the lead was used at the rate of 1-100, or reduced to one-half the normal dosage. In plot 3 the control obtained was excellent, giving for the two varieties of apples 2.2 and .2 percent worms. In plot 4 the percentage of worms increased to 4.9 and 1.1, indicating that the more dilute application throughout the season is not equally effective, laboratory tests and theories to the contrary notwithstanding.

The calyx spray only was applied in plot 6, using a dilution of 3-100 and going over the trees a second time to make the application thorough. The percentage of worms for the two varieties is 14.0 and 3.1, which on the basis of the check is remarkably low. On the practical basis, however, the infestation is entirely too high and indicates the fallacy of such a practice for Western Oregon conditions. Plot 9 illustrates just the opposite condition, where the calyx spray was omitted and the succeeding sprays duly applied. The arsenate here was used throughout the seasonal schedule at the standard dilution of 2-100. Here we obtain 4.2 and 5.6 percent worms. Again the infestation is high and indicates the impracticability of going to either extreme.

Plots 7 and 8, with plot 2 already discussed, include those plots in which the use of nicotine sulfate for worm control was tested. As indicated in the results summarized above for plot 2, substituting the nicotine for the lead in later applications would appear inadvisable as a general practice. In plot 7 nicotine sulfate with fish-oil soap as a spreader was used throughout the seasonal spray schedule. The dosage was increased in the last summer spray. The percentage of worms for the two varieties was 8 and 7.9. In plot 8 the standard lead arsenate spray of 4-200 was used throughout the season, combining nicotine sulfate with the lead spray for the late summer application. The total infestation here for the two varieties is 1.5 and 1.2 percent worms, or nearly perfect control.

For the calyx spray in plot 8, soap was added as a spreader. Serious burn resulted, rendering the further use of soap with arsenate inadvisable. One very noticeable fact in connection with this burn where soap was combined with the arsenate was that the burn was general over the whole tree, and on the first trees sprayed from this tank widespread and serious. Toward the end of the tank, or the last trees sprayed, the burn was not so general or severe. In fact there is a fairly uniform and gradual decline in the severity of the injury from the first trees sprayed to those last treated from this tank.

Plot 5 was sprayed with magnesium arsenate, a new form of commercial arsenate. The control was fairly good, 5.4 and 1.1 percent. In these tests a marked foliage burn, accumulative in its action, was noticeable. This tendency to burn was not so evident late in the season, but was noticeable at harvest time in the marked defoliation of the trees

in this block. Magnesium arsenate is worthy of further trials; improvement in standardizing manufacturing practices should result in minimizing the chances of burn. Growers, however, should probably consider this substance for the present in the experimental stage and use magnesium arsenate sparingly until further tests have more clearly established its status as a spray for commercial orchard use.

LABORATORY TESTS WITH SPREADERS, 1919

The laboratory experiments with spreaders were continued during 1919 and included attempts to develop new materials for use as spreaders; the improvement of promising spreaders by the addition of phosphates, sulfates, etc.; a study of the different methods of adding caseinate to the spray solution as affecting its value as a spreader; and improved methods of determining the relative wetting powers of spreaders.

New Materials. In an attempt to develop additional materials of value as spreaders in the spray solution a great number of materials and combinations were tested. Considering price, availability, ease of preparation, and effectiveness, none of the substances tested was superior to some of the spreaders already developed. Among the substances and combinations tested were the following: aluminum sulfate, 3 parts, hydrated lime 10 parts; dextrine 1 part, hydrated lime 2 parts; kaolin; kaolin 3 parts, hydrated lime 10 parts; barium sulfate and hydrated lime equal parts; chromium fluoride 1 part, hydrated lime 3 parts; calcium chromate 1 part, hydrated lime 3 parts; lead chromate 1 part, hydrated lime 3 parts; corn, potato, wheat, arrowroot, and soluble starch alone and in various combinations.

Aluminum sulfate and lime has been used as a spreader, but in our tests showed little to recommend it. None of the materials showed exceptional qualities.

Improving Spreaders by Addition of Phosphates, Sulfates, etc. The improvement of the properties of spreaders by the addition of phosphates, sulfates, etc., was suggested by Oswald[8] in his discussion of colloids, where he remarks about as follows: "The addition of extraneous substances: sulfates, citrates, phosphates, etc., all increase the viscosity of aqueous colloids of the nature of gelatine, particularly and to a greater degree when added to pure water. Iodids, bromides, cyanids, and certain chlorides decrease viscosity * * *."

Tests thus far have been preliminary in character and productive of no results of consequence. Among the materials tested are the following.

No. 1 Caseinate 10 parts, magnesium phosphate 1 part
No. 2 Caseinate 10 parts, barium sulfate 1 part
No. 3 Caseinate 20 parts, copper phosphate 1 part
No. 4 Caseinate 10 parts, cadium sulfate 1 part
No. 5 Caseinate 20 parts, aluminum sulfate 1 part
No. 6 Caseinate 10 parts, calcium phosphate 1 part
No. 7 Caseinate 20 parts, chromium phosphate 1 part
No. 11 Glue 10 parts, magnesium sulfate 1 part
No. 12 Glue 20 parts, chromium phosphate 1 part
No. 13 Glue 20 parts, copper phosphate 1 part

None of the combinations with caseinate appeared superior to caseinate alone. None of the combinations with glue appeared superior to glue

[8]Oswald and Fischer. 1917. Theoretical and Applied Colloid Chemistry. Wiley & Sons.

alone. More elaborate tests along this line in cooperation with Mr. Robinson in chemistry are planned for 1920.

Methods of Adding Caseinate as Affecting its Value. More or less difficulty has been experienced by growers and cooperators in attempting to prepare caseinate for use in the spray solution. Where inexperienced persons attempt to mix the caseinate into a thin paste, for one of many reasons they develop a glue-like article, difficult to stir or get out of the mixing vat, almost impossible to work through the strainer of the spray tank, and when finally added likely to collect in "gobs" at the bottom of the tank, and stop up spray hose, nozzles, etc. A little practice with small samples, following implicitly directions for mixing, will obviate these difficulties. Because of the too frequent complaint concerning this difficulty, however, experiments were made to determine the relative effectiveness of various methods of procedure in adding the caseinate to the solution. Caseinate here referred to is in all cases powdered casein 1.5 parts, hydrated lime 3.5 parts, thoroughly and uniformly mixed.

Three methods of procedure in adding the caseinate were followed, using 2 grams of caseinate and 8 grams of powdered lead arsenate in all cases. The materials were added to partially filled 1000 c.c. graduated cylinders, water added to make 1000 c.c. of solution, the cylinders uniformly agitated and suspension, spread, and "capillary rise" tests made of each to determine comparative values.

No. 1. Caseinate 2 grams, lead arsenate (powdered) 8 grams. The two materials were mixed thoroughly, then added direct (dry) to the solution.

No. 2. Proportions and preparation same as in No. 1. The materials were stirred to a thin paste by slow additions of water and added to solution.

No. 3. Proportions same as in No. 1. Materials not mixed. Arsenate added direct to solution. Caseinate made into thin paste by slow additions of water and much stirring, then added to dilute arsenate solution.

Results of Tests. No. 1 and No. 3 approximately equal. Such slight differences as were apparent favored No. 3, but the actual difference is of no practical importance. No. 2 is decidedly inferior.

Capillary Method for Determining Relative Wetting Power of Spreaders

One of the interesting features of our earliest studies of spreaders was the marked variation in the effective wetting capacity of a given solution for different surfaces. A solution which showed remarkable wetting powers on apple foliage need not prove of equal value on apple fruit. Because a solution showed great promise as a wetting agent on a glass surface need not indicate that it would prove particularly effective as a spreader in a spray solution for all leaf and fruit surfaces. Vermorel and Dantony[9] discuss this point in detail. Cooper and Nuttall[10] likewise discuss this point and expose the fallacy of most methods in common use for establishing these comparative values.

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[9]Vermorel and Dantony. 1912. Tension superficielle et pouvoir mouillant des insecticides et fongicides. Compt. rend. Acad. Sci. CLIV, p. 1300.

[10]Cooper and Nuttall. 1915. The Theory of Wetting and the Determination of the Wetting power of dipping and spraying fluids containing a soap basis. Jour. Agri. Science VII, p. 219.

Our interest was primarily in the ability of a solution to wet the surface of an apple. Following various attempts to obtain a definite reliable test, the use of capillary tubes and the determination of the comparative wetting ability of different solutions by the corresponding capillary rise was developed.

Procedure. Obtaining the Wax. The surface of the apple is covered with a waxy substance which must function, from our standpoint, as the factor to be reckoned with in attempting to wet or cover the fruit with a spray solution.

To obtain a fair amount of this wax, approximately one peck of Ben Davis apples was employed. The wax was extracted with petroleum ether. A large beaker was filled about two-thirds full of the liquid and covered with a watch-glass to retard evaporation. From one to three apples were suspended on strings by the stem and immersed in the ether for approximately one-half minute, the watch-glass being in place at all times except during the actual introduction and removal of the apples.

The extract, in ether, so obtained was placed on a sand bath and the ether driven off. No careful study has been made at this experiment station of the resultant extract which we have provisionally termed wax. The cooled wax is somewhat of the consistency of a high-melting paraffin, white with a tinge of yellow, and with a faint aroma of the apple fruit.

The Capillary Tube. Heavy glass tubing of calibre approximating 1.8 mm. was used. The calibre was carefully checked for uniformity and found perfect. Tubes seven inches long were then prepared, cleaned carefully, and dried by suction and finally with heat.

The wax and tubes were then placed in an incubator, set at 100 degrees centigrade. At this temperature the wax was rendered liquid. When ready to coat the walls of the tube with wax a bit of rubber tubing was slipped over one end of the glass tube, the other end of the tube was inserted in the liquid wax, and the wax drawn into the tube. The finger was then placed over the free end of the glass tube, the rubber tubing removed, the tube inverted and, by means of clamps, set vertically in the incubator to drain.

After all the tubes, 7 in number, were treated and allowed to drain for a sufficient period, the tubes were removed from the incubator, still held in a vertical position, and slowly cooled at room temperature. When cool the interior walls of the tubes were found to be smoothly and evenly covered with a thin coating of wax. At what had been the lower end of the tube as it hung suspended in the incubator was a large drop of wax which in all cases failed to drain from the tube. One-fourth inch was removed from this end of the tube and in using these tubes for our tests the opposite end in all cases was immersed in the liquid.

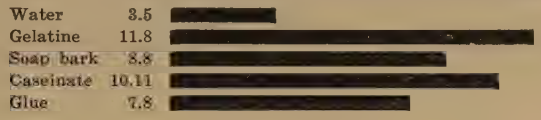
Testing the Solutions. Standard dilutions of the most promising spreaders were carefully prepared. Preparation dishes of 50 c.c. capacity and uniform in every way were used as containers for the liquid. After filling the containers sufficient time was allowed for all bubbles to leave the solution. The capillary tubes were then carefully introduced

into their respective solutions and readings made. Readings were repeated several times until uniform results were obtained. The following spreaders were tested:

No. 1 Water as a check
No. 2 Gelatine 2 grams to 1000 c.c. water
No. 3 Soap bark 2 grams to 1000 c.c. water
No. 4 Caseinate 2 grams to 1000 c.c. water
No. 5 Glue 4 grams to 1000 c.c. water.

The final results are presented in the form of a graph in Fig. 11. Based on field observations and other tests, the results surely indicate approximately the relative values of the materials as a wetting agent for the surface of the apple fruit, and therefore their relative values as spreaders. It is reasonable to assume that had the calibre of the tubes been smaller, the rise of the solutions would have been correspondingly higher. It is our belief however that the relative values would remain approximately constant.

FIG. 11. RELATIVE CAPILLARY RISE OF SPREADERS



THE CALCIUM ARSENATE SPRAY TESTS

A summary of the earlier work at the Oregon Agricultural College Experiment Station with the calcium arsenates is contained in two reports[11] published during 1917. Some of the earlier tests on toxicity are included with the reports on lead arsenate. See Table V. Other tests of a similar nature were made on the comparative toxicity of calcium arsenate and its effect on foliage. Summarized, this early work indicated a very high toxic killing efficiency for the calcium arsenates, but, due to excessive burning, precluded their use alone as a general practice in commercial orchard spraying in the Northwest.

Because of their high killing efficiency and comparative low cost, additional investigation of the possibilities of calcium arsenates was undertaken. Pure calcium arsenates were prepared,[12] as was done in the case of the lead arsenates, and methods perfected for their production. This chemical work was outlined and developed in its entirety by Mr. R. H. Robinson. No attempt will be made here other than to summarize some of the essential details of this work as it applies to our insecticide investigations.

Two calcium salts, the acid calcium arsenate and the neutral or basic calcium arsenate, known respectively as $CaHAsO_4$ and $Ca_3(AsO_4)_2$ were prepared in the pure form, both of which give much promise as insecticides. The chemical and physical properties of the two salts, including the specific gravity, solubility, and relative stability were determined. The specific gravity and fineness of division, physical properties so

[11] Lovett and Robinson. 1917. Arsenic as an insecticide. Jour. Econ. Ent. X, p. 345. Lovett, A. L. 1918. The Calcium Arsenates. Jour. Econ. Ent. XI, p. 57.

[12] Robinson, R. H. 1918. The Calcium Arsenates. Ore. Agric. Col. Exp. Sta. Bul. 131.

essential in a powdered spray to permit of the efficient spread on foliage and suspension for a reasonable time in solution, were found to be satisfactory. Both materials when subjected to severe tests were found to be somewhat soluble. The calcium hydrogen or acid arsenate is decidedly soluble, approximating the amount shown by field tests to cause serious burning and indicating that this salt should not be used alone as a spray. The tricalcium, neutral or basic arsenate is only slightly soluble and would appear to be a safe spray material to use alone. From the standpoint of stability the basic arsenate again showed to advantage, while the acid arsenate proved very unstable, permitting the formation of harmful amounts of soluble arsenic.

EXCESS LIME OR LIME SULFUR TO RENDER MATERIALS SAFE

Considered from a practical standpoint it is evident that if some substance could be added to the spray which would prevent solubility and reactivity it would prove beneficial in the use of neutral calcium arsenate, $Ca_3(AsO_4)_2$, and absolutely essential if acid calcium arsenate, $CaHAsO_4$, were to be rendered safe as a spray solution. Ordinary quicklime, CaO, should fulfill the requirements, the $Ca(OH)_2$ on becoming soluble reacting with any arsenic going into solution and forming more calcium arsenate. As in the previous cases this proposition was subjected to a variety of elaborate chemical tests and following a careful analysis of the results the conclusion is that wherever CaO is present in even slight excess so that $Ca(OH)_2$ may be found qualitatively in solution, no soluble arsenic will occur. One precaution must be observed here; be sure the lime is CaO and not $CaCo_3$, as this latter material reacts very slowly with the calcium salts and does not prevent the formation of soluble arsenic. If one part of CaO is added for an equal amount of either acid or basic calcium arsenate in the solution, no burning of foliage should result from the spray due to the formation of soluble arsenates.

Because of the desirability of combination sprays, studies of the calcium-arsenate lime-sulfur mixture were undertaken. Following the reports of G. E. Sanders as included in the proceedings of the Entomology Society of Nova Scotia for 1916 and communications from him on the success of the calcium-arsenate lime-sulfur combination under field tests, more elaborate experiments with the pure materials in dilute lime-sulfur solutions were conducted.

The tests were in all cases favorable beyond expectation. In addition to the pure salts, commercial calcium arsenates consisting of a mixture of $CaHAsO_4$, $Ca_3(AsO_4)_2$, $CaCO_3$, and other materials were tested with the lime sulfur. With all the materials no chemical reaction occurred and all the constituents remained constant. These tests included samples of the dry lime sulfur now on the market which likewise was apparently a safe combination. A careful review of the article by W. M. Scott[13] on arsenate of lime would indicate that in his tests the absence or presence of lime sulfur in the solution was correlated with the presence or absence of burn.

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[13]Scott, W. M. 1919. Arsenate of Lime or Calcium Arsenate. Jour. Econ. Ent. VIII. p. 194.

Analyzed for total arsenic it was found that the calcium salts contain more than twice as much of the active killing agent as do the corresponding pure lead salts. Theoretically then for spraying purposes only one-half as much calcium arsenate is required as of the lead arsenate. Preliminary laboratory tests with sprayed foliage, using a total of fifty tent caterpillars for each spray, indicated a very high toxicity, particularly for the $CaHAsO_4$. Mr. F. E. DeSellem[14] of North Yakima, Washington, reported in 1916 very favorable results against codling-moth with a commercial calcium arsenate. At a dilution of a half pound to fifty gallons he obtained a total of 99.5 percent clean fruit.

PRELIMINARY FIELD TESTS

Field spraying experiments of a preliminary character were undertaken using pure and commercial calcium arsenates alone and in combination.

The following materials and combinations were used.

Neutral calcium arsenate	$Ca_3(AsO_4)_2$
Acid calcium arsenate	$CaHAsO_4$
Calcium ammonium arsenate	$CaNH_4AsO_4$
Latimers calcium arsenate	Commercial
Riches Piver calcium arsenate	Commercial

These materials were used alone and in combination with an excess of CaO and of lime sulfur at strengths of 2-50, 1-100, and 1-400. For example, neutral calcium arsenate was used as follows:

1. $Ca_3(AsO_4)_2$ 2-50 (at the rate of 2 pounds to 50 gallons)
2. $Ca_3(AsO_4)_2$ 2-50 plus lime 1-50
3. $Ca_3(AsO_4)_2$ 2-50 plus lime sulfur 1-40
4. $Ca_3(AsO_4)_2$ 1-100
5. $Ca_3(AsO_4)_2$ 1-100 plus lime 1-50
6. $Ca_3(AsO_4)_2$ 1-100 lime sulfur 1-40
7. $Ca_3(AsO_4)_2$ 1-400
8. $Ca_3(AsO_4)_2$ 1-400 plus lime 1-50
9. $Ca_3(AsO_4)_2$ 1-400 plus lime sulfur 1-40

The trees were six-year-old apple trees, and all materials were applied in duplicate. The date of application was June 15. Observations on burn were made on June 19, June 22, June 27, July 2, and July 18.

Many notes were compiled from these preliminary field tests but they are not deemed sufficiently conclusive to warrant taking time for more than the following brief summary.

1. The commercial materials showed decidedly better adhesive properties than did the pure materials.

2. The check trees, those without the addition of either lime or of lime sulfur, gave a decided burn, accumulative in action.

3. The addition of lime or of lime sulfur materially reduced the burn and as a rule entirely prevented serious burn.

4. The addition of lime sulfur did not afford as perfect protection from burn as did the lime.

It is a matter of common observation that lime sulfur used in midseason, even at a very high dilution on foliage which has not been sprayed previously that season with lime sulfur, will sometimes give a serious

[14]DeSellem, F. E. 1916. Rept. Hort. Dept. Yakima Co. Wn. 1916. p. 45.

burn. Likewise scab areas are found to afford a ready spot for the beginning of spray burn and in our tests it was evident that spray injury was most usual at such points and spread in all directions from the edges of the scab area. Another factor which appeared to be of equal importance in determining the probability and seriousness of the burn with a questionable spray was the natural vigor of the tree. Vigorous trees with large, dark leaves seemed much more resistant to burn. Or to state it another way, materials which gave a considerable burn on average trees and on those showing more or less scab infection, in many cases showed no injurious effects when applied to vigorous, clean-foliaged trees.

CALCIUM ARSENATE TESTS IN 1918

Actual commercial tests using a brand of commercial calcium arsenate were made in our orchard tests along with the lead arsenate and spreader tests. Lime sulfur at the usual dilutions was present in the earlier applications but in all applications throughout the season in these commercial tests, two pounds of quicklime was added to the spray solution for every pound of calcium arsenate used. A summary of these tests and the comparative effectiveness of calcium arsenate in codling-moth control is included in the report of field tests in 1918, as given in Table XII.

Summarized, it may be said that calcium arsenate was superior in worm control in these tests to any lead arsenate used alone and was only excelled where a spreader was added to a lead to increase its effectiveness.

In addition to these commercial orchard tests for worm control various field tests were made, including:

1. Tests of the comparative values of commercial calcium arsenates.

2. Tests to determine the proper quantity of lime and the best time to add it to the calcium arsenate spray solution.

3. Tests of the practicability of calcium arsenate as a dust application.

4. Physical and chemical tests of commercial brands of calcium arsenate in the laboratory.

In the absence of available caterpillars for toxic tests it was possible only to check this series for comparative effect and appearance on the trees.

Test No. 1. Comparative Values of Commercial Calcium Arsenate

The commercial brands of calcium arsenates included in these tests and the dilutions and combinations used were as follows:

1. Six trees with calcium arsenate 1-50
2. Six trees with calcium arsenate 2-50 plus 2 lbs. lime
3. Six trees with calcium arsenate 2-50 plus lime sulfur 1-40

The three tests of each commercial brand were made and the following brands were included in the tests: Sherwin Williams calcium arsenate, Grasselli calcium arsenate, Corona calcium arsenate, Rex calcium arsenate, Riches Piver calcium arsenate.

While amounts are indicated on a 50-gallon basis only, 10-gallon lots of solution were prepared, the amounts of arsenate being respectively:

1-50 equals 3¼ ounces to 10 gallons of solution
2-50 equals 6½ ounces to 10 gallons of solution

The lime used was the powdered form of commercial hydrated lime, used in equal amounts with the arsenate in test No. 2, or 6½ ounces of hydrated lime to 10 gallons of solution.

The lime sulfur, testing 32 degrees Baume', was added in test No. 3 at the rate of 1.6 pints to 10 gallons of solution.

The pump was a wheelbarrow type, 10-gallon outfit, fitted with a Vermorell nozzle. The pump was, for these small outfits, an unusually effective type and developed a good pressure delivering a fine, misty, uniform spray.

The trees used were six-year-old apple trees set in closely planted rows. They were clean, sturdy, thrifty, growing trees. To insure uniform results six trees were used in each test in groups of three, in two different areas of the planting.

The date of application of the sprays was June 14, 1918. Careful field observations on burn were made on June 25 and July 12. Light showers fell on July 9-10. A brief summary of the effect of the various sprays following the final field observations shows the comparative results included in Table XVI.

TABLE XVI. FIELD TESTS OF COMMERCIAL CALCIUM ARSENATES FOR BURN

Brand	1-50	2-50 + 2 lbs. lime	2-50 and lime sulfur 1-40
Sherwin Williams	Fair burn, scattered	No burn	Fairly heavy tip and marginal burn
Grasselli	Medium serious marginal burn	Fair marginal burn	Fair marginal burn
Corona	Trace	No burn	Slight tip and marginal burn
Rex	Medium serious general burn	No burn	Trace
Riches Piver	No burn	No burn	Considerable marginal burn

Discussion of Results. Calcium arsenate alone tends to burn and is not safe for general orchard spraying. In the case of Riches Piver brand as is shown in a succeeding table on chemical analysis, the failure to burn may be accounted for in the fact of the presence in the material of an excess of lime.

Where excess lime is added calcium arsenate generally is safe to use and the danger of burn is very slight.

Lime sulfur did not prevent burn in these tests. It is reasonable to suppose the burn may be as readily chargeable to the lime sulfur as to the calcium arsenate. Considered chemically, however, their effect one on the other in combination is supposed to be mutually beneficial in neutralizing their respective tendencies to burn. Conclusions previously drawn may be reiterated on the basis of these results, that where calcium arsenate is used in orchard spraying, as a margin of safety, it is always advisable to add excess lime.

Test No. 2. Time and Manner of Adding Lime to Calcium Arsenate Spray

These tests were carried forward in the same block of trees as those above, six trees in groups of three for each test. The same outfit was used and observations on results were carried out at the same time. The materials were applied June 18, 1918. Corona calcium arsenate was employed in these tests and in each case both the lime and the poison were used at the rate of 3 pounds to 50 gallons. The following tests were performed.

1. Prepared lime and diluted for use 3 hours before adding poison and applying spray, (a) using quicklime; (b) using hydrated lime.
2. Prepared lime, diluted for use and added poison 3 hours before applying spray, (a) using quicklime; (b) using hydrated lime.
3. Prepared lime, diluted for use, added poison and applied spray at once, (a) using quicklime; (b) using hydrated lime.

Again summarizing the results following our last field observations on these tests we may state as follows: In no case was there evidence of burn, nor any conditions present to indicate the superiority of one method or material over the other. Theoretically where lime is added to the solution some time in advance, the possibility of burn is materially reduced. In these limited tests, however, there was no evidence in favor of this practice. Hydrated lime appeared to be equally effective with the quicklime as a neutralizing agent. It is much easier to prepare and add to the spray solution than is quicklime.

Test No. 3. Tests of Physical and Chemical Properties of Commercial Calcium Arsenates

Chemical analyses and physical tests of representative samples of commercial calcium arsenates were made to obtain their comparative value as a poison spray. The chemical analyses were made by Mr. R. H. Robinson of the department of Agricultural Chemistry, who kindly made the following report on his findings.

TABLE XVII. CHEMICAL ANALYSIS OF COMMERCIAL CALCIUM ARSENATES

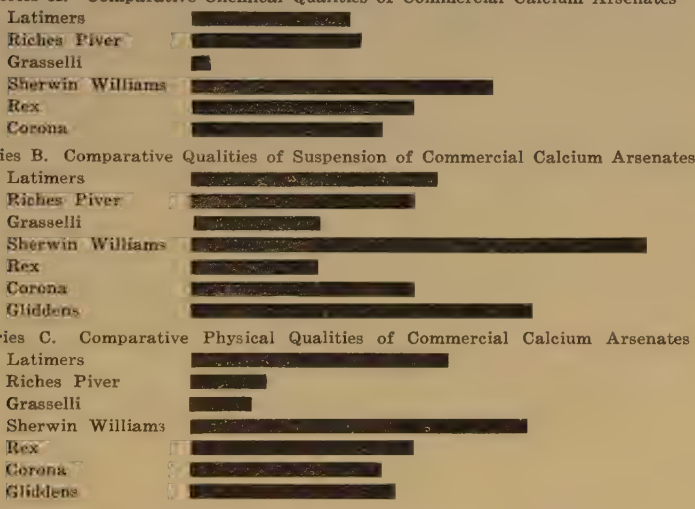
Brand	Total CaO	Soluble CaO	Total As_2O_5	Soluble As_2O_5
	%	%	%	%
Latimers calcium arsenate	40.80	1.8100	43.42	Negative
Riches Piver calcium arsenate	37.42	.9100	41.74	Negative
Grasselli calcium arsenate	42.80	1.6000	42.25	Negative
Sherwin Williams calcium arsenate	30.80	.2200	38.48	1.4100
Rex calcium arsenate	37.84	.0062	41.40	.0058
Corona calcium arsenate	43.04	.0042	47.50	Negative

Discussion of Results. Based on this analysis it may be stated that in the majority of the materials there is an excess of lime present. Though the amount of this excess lime present is variable, it detracts from the actual toxic efficiency of the poison pound for pound, and is a material which the grower can readily add himself and is in fact one which, in order to render the spray solution entirely safe, he should add. It may be therefore stated that from the practical and chemical standpoint those brands in which this excess of lime is the lowest are theoretically best.

Finally, physical tests of the comparative suspension of the materials were made using 5-gram samples in 1000 c.c. graduates with water. The general procedure was the same as in the case of the suspension tests carried forward with spreaders.

Microscopic examinations were made of representative samples of the commercial brands to determine the comparative fineness and uniformity of division of the particles. The graphs have been prepared, based on the results of these various tests with commercial calcium arsenates, in an attempt to show at a glance the comparative chemical and physical values.

FIG. 12. COMPARATIVE VALUES OF COMMERCIAL CALCIUM ARSENATES



Discussion of Results. All things considered the majority of the commercial brands of calcium arsenate are comparatively uniform in both their chemical and physical composition. Sherwin Williams stands out as a superior form, while Grasselli's is poor. The dilution of the product with lime is largely responsible for the poor showing probably, as this substance would react unfavorably in the physical tests as well as in the chemical analysis, coming out of suspension quickly and tending to coarse non-uniform particles. Chemical analysis of Gliddens arsenate was unfortunately not available.

NICOTINE SULFATE SPRAY TESTS

Following the results of F. E. DeSellem[15] of North Yakima with nicotine sulfate as a spray for codling-moth control, experiments were undertaken with this material seeking to establish its toxic value as a poison spray and to afford a satisfactory explanation of his findings.

[15]DeSellem, F. E. Nicotine Sulphate for Codling Moth Control. Ann. Rept. Hort. Dept. N. Yakima for 1916, p. 62.

Three series of tests have been made. First, to establish the toxic value of nicotine sulfate as a stomach poison for insects. Second, to find the various ways in which nicotine sulfate might prove of value for codling-moth control. Third, to find the use of nicotine sulfate in commercial field tests for codling-moth control, alone and in various combinations with arsenate sprays.

SERIES I. NICOTINE SULFATE AS A STOMACH POISON FOR INSECTS[16]

As with the toxic tests of arsenical sprays, the agent used for these tests was our common tent caterpillar (Malacosoma pluvialis). The caterpillars were collected, tent and all, from the field, principally from wild rose, and the preliminaries carried forward fundamentally as with the previous tests with the arsenates. With the exception of series A, the foliage was allowed to dry for several hours after applying the spray before introducing the caterpillars.

Experiment A. (April 9, 1916. 9:00 a. m.) Sprayed foliage of wild rose with "Pratt's Nicotine 40" 1-400, thoroughly wetting the foliage with a fine misty spray. Placed approximately six hundred newly hatched larvae of the tent caterpillar (pluvialis M.) on the wet foliage. The caterpillars exhibited a most decided aversion to the sprayed foliage, crawling about, collecting in masses and suspending themselves on elongated web ropes and dropping off. By 12:00 m. fully 60 percent were apparently dead, though none had fed. These died in a balled-up heap in the center of the mass of foliage. There was no indication of feeding. The few remaining caterpillars were restless, sick, and writhing about. Observation at 5:00 p. m. showed about all dead; some which had dropped apparently dead, showed signs of life, but were very sick. The next morning, April 10, all were dead or had left. A fair percentage of those which dropped had recovered and crawled away. One small incision in the margin of a leaf was observed, but there were no other signs of feeding apparent.

Experiment B. (April 13, 1916. 8:45 p. m.) Sprayed foliage of apple as follows:

No. 1.	Pratt's Nicotine 40	1-800
No. 2.	Black Leaf 40	1-1200

Applied as fine misty spray, thoroughly wetting foliage. Placed on table to dry. April 14, 9:00 a. m. placed approximately three hundred small caterpillars on No. 1 and a like number on No. 2. Foliage perfectly dry.

The caterpillars showed a decided aversion, were restless, crawled about, formed long web ropes and dropped off. Often one would be observed to rear the head and half of the body from the foliage, writhe about, and spew up drops of dark liquid as grasshoppers do, apparently very sick. At 3:00 p. m. 50 percent were apparently dead, the others very sick. Many which had dropped and lay curled in grotesque positions as though having died in great pain, eventually recovered (after 3 hours or more) and crawled away. The following day, April 15, a few were

[16]Lovett, A. L. 1917. Nicotine Sulphate as a Stomach Poison for Insects. Jour. Econ. Ent. X, p. 333.

observed to have fed on both No. 1 and No. 2. Where they had fed, they were apparently in all cases really dead. One fact stood out particularly, that of the many which had dropped, apparently dead, without having fed, they had almost without exception recovered and crawled away. The drop on No. 2 was a little heavier than on No. 1, with a little more feeding indicated on No. 1. The caterpillars were about all dead or had crawled away the next day, April 16, from both No. 1 and No. 2. To see if the action of the material was still effective seventy-five fresh caterpillars were placed on No. 2. The action of the caterpillars was the same as that of earlier forms, restless, sick, and dropping off.

Experiment C. (May 5, 1916.) Sprayed apple foliage with following:

No. 3.	Black	Leaf	40	1-800
No. 4.	Black	Leaf	40	1-1200

Thoroughly covered foliage with fine misty spray, and allowed to dry for six hours. Placed approximately one thousand half-mature tent caterpillars on each.

The results were practically identical with those of Experiment B with the immature forms. The material was apparently very repulsive, though no odor of nicotine could be detected. The foliage was placed where a breeze could blow across it. The caterpillars continued to act restless, dropped, writhed, and spewed. The effect of the spray on these larger forms was slower. More caterpillars were used in the tests. Daily observations were made until May 19, when approximately all had left the sprayed foliage. Each day a number would drop, lie for about three hours as though dead, then recover and crawl away. Those which crawled away collected in a mass on the sill of the window. On May 10 and 11 these forms were collected and placed on fresh unsprayed foliage. Here they fed with great gusto and apparently showed no ill effects of recent illness.

On May 11, 2 caterpillars were found dead on No. 3; the foliage showed small feeding punctures. There were 3 dead on No. 4, which also showed slight evidence of feeding. The foliage was changed on May 12, first allowing it to dry thoroughly after applying the spray. On May 19, 7 caterpillars were dead under No. 3 and 12 under No. 4. Feeding for the entire period amounted to a total of about two fair-sized leaves.

Experiment D. (May 19, 1916.) Dipped camel's-hair brushes in nicotine sulfate 40 percent, and treated nearly mature caterpillars as follows:

No. 1. Black Leaf 40, 1-800. Painted ventral surfaces of 10 caterpillars with moist brush and then placed caterpillars on fresh unsprayed apple foliage.
No. 2. Pratt's Nicotine 40, 1-800. Allowed brush to dry for 24 hours; painted ventral surface of 10 caterpillars and placed on fresh unsprayed apple foliage.
No. 3. Black Leaf 40, 1-1200. Allowed to dry 24 hours and treated as above.
No. 4. Pratt's Nicotine 40, 1-1200. Treated as No. 1.

In cases of No. 1 and No. 4 the caterpillars appeared nauseated, spewed up, and dropped off; eventually recovered.

In cases of No. 2 and No. 3 they were restless for a time but eventually commenced feeding and were apparently normal. Not sick.

Remarks on Results. Nicotine sulfate is apparently a very powerful repellent for caterpillars. They will not ordinarily feed from choice on foliage sprayed with it. Where feeding does take place, the action of the nicotine is apparently rapid and sure, even small bits of foliage sprayed with comparatively weak solutions, where devoured, killing almost instantly.

The peculiar property of nicotine sprays to which one may attribute the general sick condition of the caterpillars is explained by the report of McIndoo[17] as due to a temporary paralysis of the nerve centers by the slow volatilization of the nicotine from the foliage.

SERIES II. NICOTINE SULFATE AS AN OVICIDE FOR CODLING-MOTH EGGS

On August 31, 1917, codling-moth eggs deposited on apples were collected in the field. These eggs varied from those recently deposited to those just ready to hatch. The eggs were examined carefully in the laboratory under a binocular and the position of those appearing perfect in every way was indicated on the fruit by drawing a circle about the egg some little distance away with water-proof ink. The apples were then so cut as to leave the egg uppermost when the apple was laid on a table. The apples were then sprayed by means of a quart hand sprayer, throwing a very fine, mist-like spray. The following materials were used:

No. 1. Black Leaf 40 1-1200
No. 2. Black Leaf 40 1-400
No. 3. Black Leaf 40 1-1200 plus fish oil soap at the rate of 4 pounds to 100 gallons
No. 4. Check

The final count of results was made on September 8 and gave the following:

	Hatched	Unhatched	Total	Percent unhatched
No. 1	7	38	45	84.5
No. 2	9	36	45	80
No. 3	0	26	26	100
No. 4	19	5	24	20.8

In the case of No. 1, two eggs were parasitized; No. 2, two eggs parasitized; No. 3, three eggs parasitized; the parasites in all cases being apparently dead. In the case of No. 4, two of the unhatched eggs appeared infertile.

Nicotine sulfate is an effective ovicide for codling-moth eggs. The addition of soap renders it practically perfect in this regard.

SERIES III. FIELD TESTS WITH NICOTINE FOR CODLING-MOTH CONTROL

Experiment F. This experiment was made during the season of 1916. The tests were unsatisfactory and cannot be said to have yielded good experimental data. The immediate cause for failure was due to an unavoidable late change in plans. The factors which make the test of little value are as follows: The orchard tract available for the test consisted of a run-down apple orchard of mixed varieties with their

[17]McIndoo, N. E. 1917. Effects of Nicotine as an Insecticide. Jour. Agri. Research. VII, p. 89.

necessary individual variations in susceptibility to codling-moth attack. No comparisons were made against the standard lead arsenate application. The nicotine sulfate was used in combination with lime sulfur and without the addition of soap. The season was a very backward one and the generations of codling-moth unduly prolonged.

A brief summary of the results are included for whatever value they may have. Four applications were made: (1) The calyx spray, May 10. (2) When the eggs of the first generation were deposited, June 16. (3) When the first adults of the second generation appeared, August 2. (4) For the heavy late oviposition, September 8.

The following materials were used at each application:

1. Niagara dust sulfur 85 percent plus Corona lead arsenate 15 percent, applied as a dust spray.
2. Black Leaf 40, 1-400 plus lime sulfur at the standard dilutions.
3. Pratt's Nicotine 40, 1-800 plus lime sulfur as above.
4. Black Leaf 40, 1-1200 plus lime sulfur.

A summary of the mean percentage of wormy apples for the various plots is as follows.

Check	Plot 1	Plot 2	Plot 3	Plot 4
29.7	8.6	15.3	26.0	26.8

None of the materials gave satisfactory control; nicotine 1-1200 and 1-800 show but slight control over the check, 26.8 and 26.0 percent respectively against 29.7 percent for the check. Nicotine sulfate 1-400 gave partial control, 15.3 percent worms. The dust application gave by far the best control, 8.6 percent.

Experiment G. The second series of field tests of nicotine sulfate for codling-moth control was conducted in 1919. The results are included in the general report of sprays in orchard 2 for the season of 1919 under the discussion of spreaders. See Table XIV. These tests occurred in plots 2, 7, and 8, and consisted of the following:

Plot 2. Lead arsenate 2-100 without spreader in the first three applications; changing to Black Leaf 40 1-1200 plus fish-oil soap 4-100 in the July and August sprays.

Plot 7. Black Leaf 40 1-1200 plus fish-oil soap 4-100 for the first four applications and 1-800 for the fifth.

Plot 8. Lead arsenate 2-100 throughout the seasonal schedule, with Black Leaf 40-1-800 added in the August application.

A summary of the season's results with the percentage of wormy apples in the blocks is as follows:

Plot	Variety	Percentage wormy
2	Spitzenburgs	6.7
	Newtowns	.7
7	Spitzenburgs	8.0
	Newtowns	7.9
8	Spitzenburgs	1.5
	Newtowns	1.2

Remarks on Results. Nicotine sulfate alone is an expensive and not wholly satisfactory spray for codling-moth control. As a supplement to and in combination with the regular arsenical applications it has much promise.

SUMMARY AND CONCLUSIONS, NICOTINE SULFATE TESTS

Nicotine sulfate is a powerful repellent for tent caterpillars. Where larvae feed on the sprayed foliage it is an effective toxic agent.

Nicotine sulfate with soap is an excellent ovicide against codling-moth eggs.

As a substitute for the standard arsenical sprays for codling-moth control, efficiency and cost considered, nicotine sulfate does not show qualities to recommend its general adoption.

That its use as a supplement to and in certain combinations with the standard lead arsenate sprays might in certain cases prove highly effective is indicated by the following facts: (1) Nicotine sulfate is apparently an active repellent for chewing insects. (2) It is an effective ovicide for codling-moth eggs. (3) It is an efficient toxic agent for caterpillars. Theoretically it should be of value in the following cases:

1. Frequently a serious summer reinfestation of the green apple aphis (*Aphis pomi*) occurs in portions of Western Oregon in July. Nicotine sulfate 1-800 plus soap 4-100 might be substituted for the July codling-moth application of lead arsenate in such a case, thus handling the aphids and the apple worm with a single application.

2. In Western Oregon the most serious codling-moth injury is the so-called "September sting," occuring in late August and early September as a result of the late worms of the second generation of codling-moth. A combination of nicotine sulfate 1-800 with the standard arsenical spray applied at this time, should increase the efficiency of this late-summer application. It would be particularly advisable in such a combination to add a spreader to insure a higher efficiency for this costly spray.

Theoretically, nicotine sulfate should (1) constitute a fairly active repellent for adult moths, preventing oviposition; (2) serve as an ovicide for such eggs as have already been deposited; (3) act as a toxic agent for newly hatched larvae, causing them to drop with temporary paralysis; and (4) where feeding does take place, prove an active stomach poison.

CONCLUSION

To attempt to draw all the conclusions that present themselves from the mass of data accumulated in this bulletin would require more space and time than the present unfinished nature of the project warrants. The salient facts of the investigation are included in the summary at the beginning of the bulletin and we shall attempt here simply to discuss the results as applied to commercial orchard spraying, particularly from the point of view of improved codling-moth control.

Choice of a Lead. While there is a distinct variation in the physical properties of commercial lead arsenates, further tests are desirable before a report is made. It is hoped to present these data in a subsequent publication at an early date. All the standard brands are good, and if the capacity of the outfit and the physical properties of the solution are right they will give good results.

Calcium Arsenate. The calcium arsenates are highly efficient as a poison spray, in normal times will be comparatively cheap, and where

an excess of lime is present in the solution they are safe for use in commercial orchards. Because commercial brands are not standardized and vary greatly in their physical and chemical properties, and because lead arsenates are so uniformly satisfactory, there is probably no adequate reason for a wholesale abandonment, at the present time, of lead arsenate in favor of calcium arsenate. Where a combination of an arsenical with lime sulfur is desired, as is so frequently the case in orchard spraying, the calcium arsenate is a more compatible salt than is the lead. There is no reaction, with the subsequent production of sludge, as when lead arsenate and lime sulfur are combined. In fact, mixing improves the lime-sulfur calcium-arsenate combination, while mixing lead arsenate and lime sulfur decreases to an extent the action of both. It is the lead in the poison spray that is at least partly responsible for the losses of stock and the development of "roaring" in horses fed on hay from heavily sprayed orchards. If, as time goes on, additional evidence accumulates we may find sufficient justification for adopting the calcium arsenate as our standard poison insecticide for orchard spraying.

Magnesium Arsenate is a new insecticide on which additional data are desirable before either advocating or condemning its use. Growers are advised to use it, if at all, on a small scale only until further tests are completed.

The Use of Spreaders. The use of a spreader in the poison spray solution accomplishes a number of desirable things. By increasing the wetting and covering powers of the solution it permits us to reduce the amount of arsenic necessary for protection. By permitting a more uniform covering over the surface and increasing the adhesiveness it affords a better protection from worms. Finally, allowing the spray to dry as a smooth, even covering over the surface affords an inconspicuous coating of the mature fruit. This does away with the blotchy, conspicuous poison coating so objectionable when our apples and pears are entering eastern markets, particularly since there has recently developed a tendency to discriminate against the heavily sprayed Western fruit. The possible effect on the value of the spreader of waters used for the spray solution which contain considerable amounts of various salts has not been ascertained. It is quite possible that some waters might affect the spreader adversely and decrease or annul its effectiveness. The last word on spreaders has by no means been written. Our tests with this type of material will continue. Those showing the most promise to date are: caseinate, gelatine, glue, soap bark, oil emulsion. Considering each from the point of view of our present knowledge and basing our conclusions on availability, efficiency, compatability, cost, and ease of preparation the following may be stated:

Caseinate. At the dilutions recommended caseinate is cheap. The casein is available in any reasonable quantity, though it is probably advisable to order through a wholesale drug or chemical firm. In estimating the amount required, figure on the basis of 3 ounces of casein to every 200-gallon tank of spray. By multiplying the approximate number of tanks ordinarly required to spray the orchard by the number of applications to be given in which casein is to be used, one can arrive at a close estimate of the casein required.

The formula for the preparation of caseinate is given on page 22. We find for this purpose the hydrated or powdered quicklime equal in quality to the rock lime and much more satisfactory to work with. Care should be taken to mix the material thoroughly. A little excess lime accelerates the reaction between the two materials. In preparing for use there are two methods of procedure: (1) mixing to a paste and adding to the spray solution; (2) adding direct (dry) to the spray solution.

In preparing the paste it is extremely desirable that one experiment first with very small amounts until sure of the proper procedure. It is easy to add water too fast and drown the mixture. Where prepared as a thick paste and allowed to stand for a brief period the mass becomes of a gluey consistency very difficult to handle. Add water slowly to the mixture with vigorous stirring until the two materials, lime and casein, fuse. This reaction is chemical in nature and may be readily observed. After witnessing this phenomenon one may mix the material in almost any quantity, adding the water slowly until this breaking or fusing occurs, then diluting as rapidly as desired. Where preparing in quantities, it is advisable to take a known amount of the mixture and finally dilute with a known quantity of water to a thin paste. Then for each tank of spray stir thoroughly and remove the proper amount of the mixture.

Apparently just as good results follow when the mixture in the desired amount is added dry to the spray tank. It may either be mixed with the arsenate before adding or be added separately to the tank. In either event it is advisable to have the engine running and the agitator in motion when adding the material.

Gelatine, in our tests, proved one of the most promising spreaders of all. Considered from the point of view of efficiency and compatability it has much in its favor. Availability and cost limit its use and we can not advise its general adoption.

Glue. While in our experiments glue does not compare favorably with gelatine, a limited study of various grades of glue, made too recently to include here, warrants the surmise that brands occur that more nearly approach the gelatine standard of excellence.

For use, one pound of glue to 100 gallons of spray solution should be employed. Weigh out the number of pounds of glue required for the day's operation, place in a suitable container, add an equal number of gallons of water and let stand over night. Use one gallon of the stirred mixture to 100 gallons.

Soap Bark. While an excellent spreader, soap bark foams excessively. The powdered form appears to be of somewhat variable composition and is probably derived from different sources. The bark itself has the objectionable feature of difficulty of preparation. The general use of this spreader is not recommended at present.

Miscible Oil Emulsion. In our preliminary tests of miscible oil emulsion as a spreader with lead arsenate, the oil shows considerable merit. It is efficient, cheap, and easy to prepare. No bad effects followed its use in our tests this season. It is probably advisable to observe

caution in the use of this material until further tests have indicated that there is little or no danger of burn. This may prove the most desirable material of all.

Dilutions, Combinations, and Suggestions for Poison Spray Schedule. A dilution of 3 pounds of arsenate to the 200 gallons of solution is considered sufficient for the earlier codling-moth applications in commercial orchards where a spray program is regularly followed and the worm infestation is not high. Where the worms are particularly serious an increase in the poison dosage is advisable. For the last summer application, observations and experiments indicate the advisability of increasing the poison dosage by one-half or to 4½ pounds to the 200 gallons. The addition of a spreader will pay big returns in higher efficiency of the spray, even though the amount of arsenate is not reduced.

The addition of nicotine sulfate to the last summer poison-spray application suggests itself. Sufficient commercial tests have not yet been performed to establish the value of the practice. Should nicotine be as assumed (1) a repellant for the adult moths, it should limit oviposition; (2) an ovicide for codling-moth eggs, it should destroy any unhatched eggs present at the time of its application; (3) a poison for caterpillars, it should serve as an additional protection to the surface of the fruit from any young worms attempting to enter. Theoretically, it would not be necessary to increase the dosage of poison were nicotine sulfate added to the solution. To obtain the highest efficiency from this combination of arsenate and nicotine, the use of a spreader in the solution would be essential.

In mixing lead arsenate and lime sulfur a minimum reaction with sludge formation will result where the materials are combined in a dilute form. The results of our tests suggest the following practice: Add the lime sulfur to the filling tank. When the tank is nearly full start the engine and while the agitator is in motion add the arsenate slowly. Powdered arsenate may be added directly to the spray solution. For best results in mixing have the engine running and add the powder slowly.

No attempt has been made to compile an exhaustive bibliography of the mass of literature that has accumulated on the various phases of insecticides and codling-moth control presented in this bulletin. All available sources of information have been freely consulted, but have not influenced or modified materially our project or plans. Of those tests carried forward by competent investigators, where conditions are comparable to those obtaining in our experiments, no extreme variance is apparent that warrants our attempting to correlate the results.